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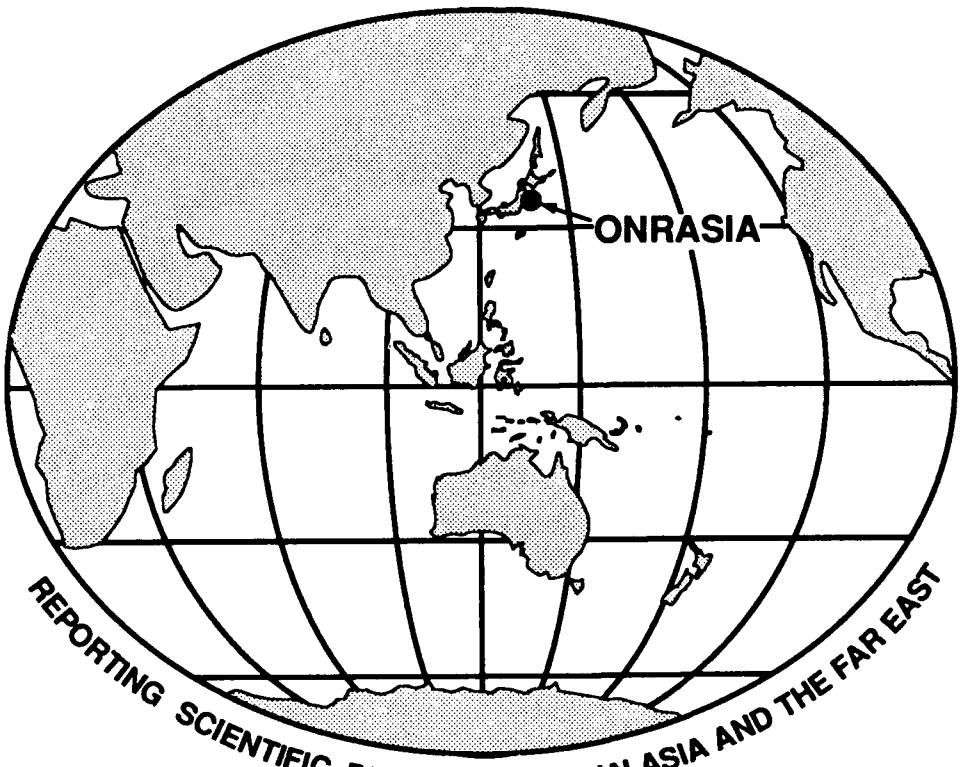

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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONRASIA, with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest. This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large. It is available free of charge to approved members of the DoD scientific community. Send written request describing DoD affiliation to: Director, Office of Naval Research, Asian Office, Unit 45002, APO AP 96337-0007.

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Material Science

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Ocean Science

The highlights of the symposium and workshop held in Hong Kong, from 3 to 4 March 1993 are presented here. The purpose of the symposium was to assess the status of environmental remote sensing globally and specifically in the East Asian area. Also, what role the new Hong Kong University of Science and Technology (HKUST) must play in the development of remote sensing research is described.

General

The Research Development Corporation of Japan (JRDC) is the key organization that implements policies for the Science and Technology Agency (STA). The Agency is directly under the Prime Minister of Japan, and its activities are funded by the Japanese Government. The Agency's main interest lays in the promotion of basic research, technology transfer, and international research exchange.

SIBRIEFs

Scientific Information Briefs

NUMERICAL LINEAR ALGEBRA AND PARALLEL COMPUTING IN JAPAN, 8 APRIL 1993

INTRODUCTION

The following paper that reports activities in numerical linear algebra and parallel processing in Japan was submitted by D.K. Kahaner, but was prepared by:

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Dr. Ashby visited Japan for the first time in March 1993 to present two lectures on numerical linear algebra and to hold technical discussions with Japanese colleagues on parallel computing. He has prepared the following report, to which I (D.K.K.) have added some annotations and other details, as appropriate.

SUMMARY

I presented an invited lecture on orthogonal error algorithms at the Ninth Symposium on Preconditioned Conjugate Gradient Methods, held at Keio University (Yokohama). During this meeting, I discussed iterative methods for linear systems with several of the attendees. Also, I gave a seminar lecture on polynomial preconditioned conjugate gradient (CG) methods in the Mathematics department of Keio University. I also visited the University of Tokyo, U.S. Office of Naval Research Asia, and NEC to discuss scientific computing with colleagues at those institutions. As a result of these discussions, I learned that Japanese computer manufacturers and researchers are concentrating on moderately parallel vector supercomputers rather than on massively parallel processing.

KEIO UNIVERSITY

The primary purpose of this trip was to visit Professor Takashi Nodera of the Mathematics Department at Keio University and to participate in the Ninth Symposium on Preconditioned Conjugate Gradient Methods, which he organized.

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When I arrived, Nodera gave me a tour of the Department's research and computing facilities. The newest computer on campus is a FujitsuVPX-220 vector machine; there are no massively parallel machines at the university. However, there are scores of personal computers set up in classrooms for hands-on instruction. In addition, the department boasts a varied collection of Sun workstations.

I gave a seminar lecture on Adaptive Polynomial Preconditioning for Hermitian Linear Systems in the Mathematics Department. Polynomial preconditioning is well-suited to vector and/or parallel machines and is currently a topic of considerable interest in the United States. In Japan, on the other hand, this technique does not appear to be too well known. Instead, most Japanese scientists use ICCG (incomplete Cholesky CG). I believe that this is because of the scarcity of massively parallel processors (MPPs) in Japan. As MPPs become more widely available, it is my opinion that the limitations inherent in incomplete factorizations will force Japanese researchers to consider alternative precon-

ditioning techniques, including polynomial preconditioning. The talk was well-received, and there were many questions during the discussion period.

The next day I gave an invited lecture, A Matrix Analysis of Orthogonal Error Algorithms at the Ninth Symposium on Preconditioned Conjugate Gradient Methods. This annual event brings together researchers from throughout Japan, as well as one or two invited lecturers from abroad. This year, Professor K. C. Jea (Fu Jen University, Taiwan) and I were the invited speakers.
[Prof. Jea is a former student of D. Young (University of Texas), DKK.]

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UNIVERSITY OF TOKYO

Dr. Yoshio Oyanagi of the University of Tokyo also participated in the Keio conference. He invited me to visit his campus a few days later.

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Oyanagi showed me his laboratory in the morning. The computing facilities at the University of Tokyo appear to be more extensive than those at Keio University. The newest machine is a four-processor Hitachi that boasts a peak performance of 32 Gflops. According to Oyanagi, it has 2 GB of main memory and another 16 GB of secondary storage (similar to an SSD). Oyanagi's research group also has access to a 64-processor machine. The University plans to acquire a 200-node MPP in the near future. It is interesting to note that the University does not purchase any of its large machines, instead rents them (at a cost of about US$10M per year). This practice, which allows the University to more easily upgrade its computing facilities, is gaining proponents in the United States of America.

After the tour, I met with Oyanagi and one of his graduate students, Osamu Tatebe, to discuss their work on preconditioned conjugate gradients. Tatebe is investigating the use of multigrid as a preconditioner in CG methods; his preliminary results are quite impressive. He compared his (multigrid CG) MGCG method against ICCG and conventional multigrid on a convection-diffusion problem on the unit square. To make the problem interesting, he superposed a T-shaped region in which the diffusion coefficient was much larger. This discontinuity caused problems for MG, but the MGCG method did well by converging in a constant number of iterations. (The MG preconditioner uses one complete V-cycle with two red-black Gauss-Seidel sweeps as the smoother.) A plot of the eigenvalues of the preconditioned matrix shows why: most of the eigenvalues are clustered about 1, with only a few outliers. CG does extremely well on such problems. Tatebe will present his results at the Copper Mountain multigrid conference in April. Since we will have similar discontinuities in our groundwater flow modeling effort, I am eager to try this approach.

NIPPON ELECTRIC COMPANY (NEC)

Drs. Ken Hayami and Shun Doi invited me to visit the NEC, Kawasaki facility.

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Hayami is the Research Manager for the Information Basic Research Laboratory, and Doi is the Technical Manager for the 3rd Applicatin Systems Development Department. Hayami provided a brief overview of NEC's organization. I was impressed by the number of groups working in various basic and applied research areas. He pointed out that NEC spends about 10% of its annual sales revenues on applied research and development, and about 1% on basic research. The former is expected to produce tangible results in 1 to 3 years; the latter is expected to bear fruit in 5 to 7 years.

I was then introduced to Dr. Toshiyuki Nakata, who is the Research Manager for the Computer System Research Laboratory.

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Nakata described NEC's Cenju parallel computers, which were initially developed as in-house research machines for circuit simulation, but are now being viewed as potential commercial products. The Cenju-II can have as many as 256 processors, but the existing prototypes have only 16 and 32 processors. Each node has two CPUs, one for computation and one for communication. Essentially, this project appears to be a one-man show, with Nakata doing all the hardware and algorithmic design.
[I have written about Cenju several times; it has been very successful in Spice computations. (Refer for example, to "spice", 2 July 1990; parallel.902, 6 Nov 1990; or "jhpc-pp.92, 28 Jun 1992. DKK]

Next I gave my lecture on orthogonal error algorithms, and after a short discussion period, I listened to a lecture by Dr. Takumi Washio on his overlapped multicolor ordering technique. The idea here is to develop a more efficient (in terms of vectorization) MILU preconditioner to be used with CG-like methods (e.g., BCG-STAB). Although his method has a bit more overhead than the usual multicolor ordering, it has a better convergence rate (for model problems) and takes less CPU time. This method, however, is limited in its potential for parallelism, and is therefore unlikely to be competitive on MPPs. Moreover, this method requires long (about 100) vectors. His target applications include computational fluid dynamics (CFD) and laser fusion.

In the general discussions that took place after the lectures, I learned something very interesting: NEC is primarily interested in moderately parallel (10-200 processors) vector computers. They are not pursuing massively parallel computing technologies. Doi and Hayami stated their belief that it is better to develop a machine with a few powerful vector processors; such a machine is easier to program, and also plays to Japanese strengths in VLSI design using CMOS technology. Although this may be true, I believe that this approach is shortsighted. Eventually, the same limitations that are forcing U.S. and Japanese companies to abandon single processor supercomputers will force them to adopt massively parallel computing. Problem sizes are simply growing too rapidly. Nevertheless, NEC's view appears to be shared by other Japanese computer manufacturers, and this explains their lack of interest in numerical algorithms research for MPPs. If MPPs are the wave of the future, the U.S. investments in numerical algorithms and mathematical software could help keep the United States at the forefront of large-scale scientific computing.
[Japanese scientists believe that traditional vector supercomputers are still very effective at solving real engineering problems, and that a sensible approach toward parallel computing is to start by developing systems with modest numbers of powerful processors, rather than very large numbers of less powerful ones. This view is also shared by some U.S. vendors, see for example the trajectory of work at Thinking Machines, where their newest machine has a few thousand powerful processors whereas their original developments focused on tens or hundreds of thousands of processors. Of course, it is clear that on long term we will have to figure out how to make really large numbers of processors work effectively together. DKK] -- *Steven F. Ashby, Univ. of CA*

*****

REAL WORLD COMPUTING LABORATORY AND PROJECTS 17 APRIL 1993

This report is a revision of an earlier one, "rwc-3.93", that was distributed on 12 April. Revisions are due to Dr. T. Hagemann (HAGEMANN@GMD.COJP), and Dr. Otsu (OTSU@ETL.GO.JP) and accepted with thanks.

I spent a day at the new Tsukuba Research Center (TRC) that is associated with the Real World Computing Partnership (RWC), the 10-year Japanese government program that focuses on advanced applications of computing. (Refer also to several of my previous reports, "rwc.93", 18 Jan 1993; "rwc.293", 11 Feb 1993; and others referenced there.) The RWC Partnership is administered in Tokyo by:

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But its technical heart is located in Tsukuba (one hour from Tokyo) at a brand new laboratory (TRC) that is run by:

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Last month, Dr. Shimada spent a full day showing the laboratory and describing his own views on the project (I was accompanied by Dr. T. Hagemann of the GMD, and Dr. Otsu from ETL). The Tsukuba laboratory (TRC) consists of three floors of leased space in a large new office building in downtown Tsukuba. The building also houses several insurance company offices and has two large restaurants on the top floor. (The use of leased space is common for Japanese research institutes.) Although the facilities are brand new, there are already plans to rearrange and enlarge them. Most scientists have individual, spacious office modules with doors organized around a central common area. Shimada explained that he was inspired by the Sony's Computer Science Laboratory in Tokyo, which was set up several years ago in a similar way. Each researcher has both a Unix workstation and a Macintosh with a large color CRT, as well as the usual other office amenities, all appearing to be of high-standard quality and appearance. This is a very exceptional arrangement in Japan, where most offices are large and unpartitioned. Shimada commented that it is doubly unusual in that the research staff is mostly composed of young scientists (I noticed this too) who would never be entitled to this much space in a traditional Japanese company. (It will be interesting to see how these people fare when they transition back to their company.) In fact, Shimada's office is relatively small, in keeping with his view that it is the scientists rather than the administrators who are actually doing the real work.

Thirty people work at TRC, 5 from ETL and 17 from member companies performing research; additionally, 8 people perform administrative or management functions. There are offices and also areas of open space with computer equipment, video cameras and recorders to support the image processing and understanding research that has just begun. Otsu explained that at ETL there are researchers that are also working on RWC activities. The ETL group (about 60) includes part time researchers, but the laboratories have somewhat different missions—"more basic, elemental and explorative research at ETL while more practical and integrative research at TRC. And, there is close cooperation between ETL and TRC as well as research transfer from ETL to TRC in accordance with the progress levels in which are considered important in this RWC program, and that is the reason why TRC was located near ETL in Tsukuba." (See below for a list of research themes being developed at TRC as well as those at ETL.)

The most interesting items of equipment at this laboratory are the two recently arrived U.S. parallel computers, an Intel Paragon, and a Thinking Machine CM-5. These are located together in one room with empty space between them for the RWC's "yet to be built" parallel computer. At the time of my visit, the CM-5 was running but the Paragon was not up yet. It was explained to me, by Shimada and also by Dr. Yuba from ETL, that many of ETL researchers (especially those working on dataflow projects) will move to the RWC laboratory,

and that their ideas about the EM-4 will be used to create the RWC machine. This is consistent with my earlier reports that parallel computing activities within RWC are to be an adaption of ETL's EM-4 project (this does not exclude partners from exploring other directions). I was also told that the original RWC plan to build a one million processor parallel computer within ten years has now been cancelled. At the time this was proposed I stated that it was a very conservative project. (Also, in the West, there is a clear trend within the parallel computing community to enhance the performance of individual processors, even at the expense of reducing the total processor count.)

The 512Kb/s RWC network had been, or was just about to be opened between Japan and Germany. It will allow researchers in Europe to access the hardware in Tsukuba and share files. On my visit I was joined by Dr. Thomas Hagemann of GMD's Tokyo office, who stated that GMD is hoping to place at least one researcher at the Tsukuba laboratory within the next few months. Although GMD is the only non-Japanese organization to be a full RWC partner, I was told that several other countries are expected to join this year. As far as the United States are concerned, activities are limited to optical fabrication prototyping, and this is now at the feasibility study stage.

Shimada, who is the RWC Research Institute director, of which the Tsukuba laboratory is a part, speaks almost perfect English and has a Ph.D. from the University of Pennsylvania in elementary particle theory. He did basic research in laser technology and has been working at ETL and subsequently at MITI, with many years of experience, running a variety of ever-larger research projects for the Japanese government. He strikes me as an excellent choice to direct this project, as his views are very international and states repeatedly that he wants RWC to leave the world a long term legacy, although he admits that he is not yet sure what that might be.

In addition to the "central" Tsukuba RWC laboratory, participants may have their own "distributed" labs, where portions of the project are developed. To give a sense of the specific activities that are now in progress, below I give a list of research projects being worked on at ETL, at TRC, and at the distributed laboratories along with (in the latter case) the companies that are performing the work. Shimada explains that a mechanism for distributing information about these projects has not yet been established, and requests that readers who would like specific information should contact him. Further, Otsu notes that since ETL is a government laboratory, interaction, with the RWC projects there, should be possible even for nonmembers of the partnership. Recall that the parts of the RWC project are "Novel Functions", "Theory", "Massively Parallel Systems", "Neural Systems", and "Optoelectronics".

RWCP TRC RESEARCH THEMES

TRC Lab	Theme
Information Integration Lab	Information Integrating Interactive Systems
Active Intelligence Lab	Real World Adaptive Autonomous Systems
Mass. Par. Architecture Lab	Mass. Par. Execution Model and Architecture
Mass. Par. Software Lab	Mass. Par. Computation Model, OS, Programming Language, and Environment
Neural Systems Lab	Adaptive and Evolutional Computers

RWCP DISTRIBUTED LABORATORIES AND THEIR RESEARCH THEMES, THEORY, AND NOVEL FUNCTIONS DEPARTMENT

Name of Novel Functions Lab	Research Theme
Oki Lab	Cooperative Problem Solving based on Heterogeneous Knowledge
Sanyo Lab	Vision Based Autonomous System
Sharp Lab	Multimodal human interface with secretary agent

NEC Lab	Vision Sensor
Hitachi Lab	Information Integration Technology for applying Sign Language Recognition
Fujitsu Lab	Learning and Growth Functions for Autonomous Mobile Robot
MRI Lab	An integration of Symbol Information Processing and Pattern Information Processing
Mitsubishi Lab	Self-organizing Information Bases
NTT Lab	Parallel Information Processing Mechanisms and Attention Mechanisms in the Brain

Name of Theory Lab	Research Theme
NEC Lab	Computational Learning Theory of Probabilistic Knowledge Representations
Fujitsu Lab	Ecological and Evolution Models for Massively Parallel/Distributed Systems
Mitsubishi Lab	A Vision Processor in Neural Architecture
GMD Lab	Statistical Inference as a Theoretical Foundation of Generic Algorithms (SIFOGA)

MASSIVELY PARALLEL AND NEURAL SYSTEMS DEPARTMENT

Name of Massively Parallel Systems Lab	Research Theme
Sanyo Lab	Resource Managements in the Massively Parallel Computing
Toshiba Lab	A Massively Parallel Machine with Optical Interconnection
NEC Lab	Adaptive Massively Parallel Systems
MRI Lab	Design and implementation of a Process Oriented Programming Language
Mitsubishi Lab	Massively Parallel Object-oriented Model
GMD Lab	Development, Implementation, and Evaluation of a Programming Model for Massively Parallel Systems

Name of Neural Systems Lab	Research Theme
Toshiba Lab	Pattern Recognition based on Structured Neural Networks

OPTOELECTRONICS DEPARTMENT

Name of Opto-electronics Lab	Research Theme
Oki Lab	3-D Optoelectronics Interconnection Technology
Sanyo Lab	3-D Integrated Stacked Optical Devices for Optical Computing Systems and their Applications
Sumiden Lab	Parallel Optical Interconnection by Optical Fibers
Toshiba Lab	Multifunctional Surface Optical Devices for Optical Interconnection
NEC Lab	Electro-Photonic Processor Network
Hitachi Lab	Optical Interconnection and Signal Processing Exploiting through Optical Frequency Addressing
Fujitsu Lab	Optical Interconnection by Wavelength Domain Addressing
Matsushita Lab	Stacked Optical Computing System (STOCS)
Mitsubishi Lab	Optical Neurocomputing
Fujikura Lab	Special Light Deflector (SLD)
Furukawa Lab	Wavelength Tunable Surface Emitting LD Array
NSG Lab	Optical Bus Interconnection System (OBIS)

ETL-RWC RESEARCH THEMES

Theoretical foundation for flexible information processing
Adaptive vision system
Real-time natural language dialogue system
Conversational speech recognition/understanding
Flexible robots
Flexible association mechanism
Massively parallel computing system
Optical computing system
-- *David K. Kahaner, ONRASIA*

*****

ACTIVITIES AT SONY'S COMPUTER SCIENCE LABORATORY (CSL), TOKYO, JAPAN

In the following paper I (D.K. Kahaner) report the activities in Research and Development at Sony's Computer Science Laboratory (CSL), Tokyo, Japan. I wanted to hear about the new activities at the Laboratory since I last visited there (refer to "sony", 30 May 1990). My host was CSL's Director,

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Tokoro has been CSL's Director since its founding in 1988. Before that he was a Professor at Keio University, and even now he spends four days each week at Keio and only one day each week at CSL. With a small laboratory and 12 to 15 scientists engaged in basic research, he feels that the amount of time he spends at CSL is sufficient.

The laboratory that is located in a building in the southern portion of central Tokyo has expanded somewhat since I saw it last, but its general look remains the same. Sony's presence in this area of the city is very visible with a variety of labs and other facilities. CSL occupies one floor of a modern office building with very westernized individual offices and large common space for informal discussions. I am told that it was a model for at least one other new Japanese laboratory, the Real World Computing Laboratory in Tsukuba

Tokoro was involved in shaping the original charter of CSL, which still allows for doing basic research in Computer Science. He explained to me that the staff interact frequently with Sony's other laboratories but that those are focused heavily on development. CSL's goal is to be a window for activities that will be of interest in the next century, and possibly achieve breakthroughs in computer development. For that reason he has tried to recruit outstanding scientists and has encouraged them to work openly in an international arena by publishing in English in respected journals. CSL's corporate charter specifically states that "it is our policy to make public the results of our research and to avoid developmental activities that have as their objective increasing the profits of private corporations." Tokoro pointed out that compensation for his scientific staff is entirely unrelated to seniority and directly coupled with performance. Each researcher sets his or her own research goals within CSL's basic research themes. The latter are focused on distributed operating systems, computer networks, programming languages, and user interfaces. These also correspond to some extent to Tokoro's own research interests. It is clear that he has had an important role in defining current activities at CSL.

I asked Tokoro if there is a problem with such a loose linkage between CSL and the main-line of Sony activities, either in the form of pressure from the corporation for practical output, or from the researchers due to lack of direction. He commented that CSL's President T. Doi is on the Board of Directors of the parent company and has provided very strong support for CSL's activities. Also, he admitted that a small laboratory is a very minor mark on Sony's balance sheet, and this was a good reason for not allowing CSL to become too large

(e.g., expensive). On the last point he felt that selection of researchers with strong internal goals was essential, with some of the same self selection that occurs in university faculty. Also he encourages group collaboration to provide reinforcement. Finally, although the lab is a basic research facility, it is not difficult to see how some of their research projects (see below) could ultimately move into corporate development, and in that sense, CSL is somewhat integrated into the company's long-term strategic planning.

Tokoro explained three major projects. One is based on future user mobility. He feels that computing environments in the next decade will be widely distributed, constantly-changing, and ubiquitous. People will move with computers and will use them while moving. The simplest example would be a user who wants his computer environment to come up on a local workstation wherever he is, without having to perform a remote log in to his "home" system. Similarly, electronic mail should follow users like a cellular telephone. Currently, a user who is working at the office and wants to leave will typically save editing files and stop applications. Then these can be copied from an office workstation to a laptop and started up there. The next day he will reverse the process. (Removable hard disks, or Apple Mac's Duo are approaches to this issue.) Tokoro believes that Unix will be unable to support this level of mobility while maintaining reliability, security, and flexibility, and that other approaches are required.

For more than five years, Tokoro, students, and colleagues have been developing a fully object-oriented operating system that is focused on object mobility. Here an object should be free to move around a distributed environment, just as portable/mobile computers are moved frequently from one place to another. (Existing systems assume stability of computers and objects.) Mobile objects should also adapt to their execution environment, and be highly dependable, e.g., objects should be trusted to provide services so that tasks with deadlines will be finished on time. Tokoro has proposed a model (computational field model) that deals with object mobility. Since the semantics and properties of an object change while it is running or when it moves, this approach separates objects and metaobjects, the former being a "container" for information, the latter defining the semantics. Each object has its own group of metaobjects, and in this sense a group of metaobjects is a virtual machine. Since a metaobject is also an object, there can be metaobjects for it, leading to a metahierarchy. Migration of an object means that an object changes its group of metaobjects. Since portable/mobile computers are frequently moving around networks, an object communicating with these computers has to change its communication protocol from local to interconnected. This can occur when the object migrates to a group of metaobjects that have suitable protocol modules to communicate with these computers.

Each object can have its own properties. Some are temporary. Others, such as a name server or a directory service, are shared by many client (objects). Some objects rely on the underlying hardware, including device drivers. The properties of an object change as it evolves.

The concrete implementation of these ideas is in the Apertos (Open) operating system. The original name was Muse, but this was discarded because of naming conflicts with an existing, unrelated, product. Apertos is completely object-oriented, with a few twists for practicality. For example, it is difficult to inspect the internals of an object, because an object is protected against access from other objects, so objects must have a method provided for exposing its internals for debugging. Object management, such as invocation or scheduling, is also difficult, as access to an object's state or other information is needed. Tokoro believes that separating objects from metaobjects allows for these difficulties to be overcome.

Certainly there are other projects in object-oriented distributed operating systems: (Amoeba, Chorus, Choices, and others.) Tokoro believes that Apertos has certain advantages in the areas of encouraging concurrent object-oriented programming, as well as increasing maintainability and reusability, freeing systems programmers from kernel programming chores such as synchronization. Further, Apertos is specifically designed for a large-scale open distributed system featuring mobile computing.

The current status of Apertos is as follows: It has been implemented on a Sony News Workstation using C++, and it is being implemented now on a MIPS R3000 workstation. Implementation on a 68000-based or similar system is claimed to be fairly easy. Tokoro told me that a "hacker" could do this in at most two months. A researcher at CSL, Yasuhiko Yokote (Email: YKT@CSL.SONY.CO.JP), told me that they hope to port the system to a PC in the near future. Apertos is thought of as

being at the "beta" test level. Tokoro is interested in locating colleagues who want to experiment, and will make Apertos available to them in source form for use in nonprofit institutions. However, my inclination would be to let CSL staff port to the system to a workstation that is more widely available in the West.

(In this context, I asked Tokoro what features Sony felt it could bring to the workstation arena to encourage sales of its News or follow-on products, given that Sun and HP dominate the workstation market in Japan so heavily. He felt that people might prefer Sony's product on the basis of size, silence, (e.g., human interface), and of course interesting applications. They certainly will have a tough battle in this highly competitive sector.)

Another major project falls in the general area of facial displays. The background for this is Tokoro's concept of an "intimate computer". He envisions a small computer that can accept verbal commands, and responds not only verbally, but also with an appropriate facial display of a person (wife, friend, teacher, or other) known to the user, and with expressions that are meaningful to the discussion context. Of course, this is a very advanced idea, and the CSL staff has a long way to go. Also, advanced interfaces are being studied by many other research laboratories. But this particular project seems to me to be quite consistent with Sony's consumer product and market experience, more so than the workstation. One step in this direction was Sony's Palmtop, pen-based system. This was cute and interesting, but Tokoro and I agreed that typing was more comfortable for us than writing. Nevertheless, the concept of a small, really personal, computer is unassailable.

Work on facial displays is being led by Dr. Akikazu Takeuchi (Email:TAKEUCHI@CSL.SONY.COJP) who showed me several of the research activities. Research papers on this subject are often presented at human-computer-interface conferences, so I will only summarize the key points here. A subject's facial image is input, either by video camera, photo, etc., and then a wire frame model is built via 500 polygons. The face can be rendered by using a skin-line surface material with Gourand shading or by applying a texture map taken from a video frame or picture. This can be tuned manually (via typical surface fitting shape functions) to allow a 3-D model that can be rotated and animated. Facial display is realized by local deformation of the facial polygons, by using an underlying muscle model from K. Waters (16 muscles and 10 parameters controlling mouth opening, jaw rotation, eye movement, eyelid opening, and head orientation.) Various expressive facial movements can then be built up by moving eyebrows, mouth, head, to embody emotion such as agreement, anger, surprise, and others. At run time, the animation subsystem awaits a request from the speech subsystem, which specifies values of the 26 parameters, based on a simple linear differential equation specifying the rate of change of each of the parameters. About 20 to 25 frames per second can be realized on a SGI workstation. I found the face construction aspect of this project fascinating, and in fact Takeuchi has built up a lovely interface that he calls a "face construction lab", and an "interactive facial animation testbed". These would be of great interest to anyone working in the area of facial processing. (Some of the underlying modeling is collaborative with Keith Waters. Also, Steve Franks, who had a visiting internship at CSL last year, helped Takeuchi with this project and jointly implemented the interactive facial animation testbed.)

For the speech subsystem, voice input is acoustically analyzed by a sound processing board. A speech recognition module outputs word sequences that are assigned higher scores by a probabilistic telephone model. These sequences are syntactically and semantically analyzed and ambiguities removed by using a loose grammar and restricted domain knowledge. From the semantic representation of the input, a plan recognition module extracts the speaker's intention. ("I am interested in Sony's workstation" leads to "he wants to get precise information about Sony workstations".) The intention output generates a response that is output by a voice synthesis module. Each module except the very last, can send messages to the facial animation subsystem about which facial display should be generated. In situations where speech inputs are not recognized, or otherwise invalid, a display corresponding to "not confident" is displayed, a rather quizzical look on the display face. At the moment various experiments are being conducted to measure the success of the system. It is a very interesting project. But, even with a great deal of effort, it still has only a modest vocabulary and clearly there is much more opportunity to develop it further.

Another project that I did not see demonstrated was network protocols to support a moving host. This is a network layer that has been slid above IP and below TCP, all sitting on top of Unix providing

for host migration transparency via the concept of a virtual network.

Director Tokoro, because of his strong academic connections, has a very open view of the research at CSL, and has encouraged visits by western scientists, and free discussions. CSL has had a large number of short-term visitors and at least a few long-term western visitors. However, for the latter to be successful, Tokoro emphasizes that it is important that there be a specific plan of collaboration. He definitely wants to encourage such planned visits, as opposed to just a "drop-in" sabbatical.
-- *David K. Kahaner, ONRASIA*

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FUZZY CONTROL OF UNMANNED HELICOPTER, 12 APRIL 1993

I have written several reports on the use of fuzzy systems theory for the development of an unmanned helicopter. This work has been on-going at the Tokyo Institute of Technology (refer to "helicopt.92", 24 Jan 1992; and "helicopt", 5 Aug 1991.) The principal investigator is Professor Michio Sugeno. Although there did not seem to be much feedback from the readers when I wrote these reports, western scientists have shown significant interest in the work. Recently, two western researchers, M. Griffin (UA Technologies Research Center, U.S.A.) and A. Bastian (Volkswagen, Germany) have been working with Prof. Sugeno on various aspects of this project. Also, a NASA scientist will shortly visit the laboratory to hold additional discussions with the group. Sugeno, Griffin, and Bastian have written a summary of their work that they will present at the IFSA (International Fuzzy Systems and Applications) conference to be held in Korea later this year. They were kind enough to give me a prepublication copy that I have cleaned up for electronic distribution; I have removed the figures and made a few typographical changes; this version is presented below, with their permission.

The success of fuzzy control in Japan is unmistakable, at least in applications. In addition to an almost endless stream of consumer products that use fuzzy and now neuro-fuzzy, an effort is also being made to apply these techniques to much larger and more complicated applications. For example, fuzzy control is now being developed to run a Sake factory. Prof. Sugeno seems to have a significant and steadily growing stream of funds to support his research, which is expensive because of the required hardware. The present government funding for LIFE for fuzzy research will end in 1995. The main center where the research is done is here; however, I am told that a new and much larger program will probably replace the current one when it expires, but the details have not yet been worked out.

FUZZY HIERARCHICAL CONTROL OF AN UNMANNED HELICOPTER

This paper will be presented at IFSA'93 by M. Sugeno; M.F. Griffin, who is currently on leave from United Technologies Research Center, E. Hartford, CT, U.S.A.; and A. Bastian, who is currently on leave from Volkswagen AG, Research Center, Wolfsburg, Germany. They can be reached at,

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ABSTRACT

This paper, which will be presented, describes the recent developments in the Sugeno Laboratory project for fuzzy control of an unmanned helicopter. The controller for the unmanned helicopter is hierarchical in design and includes qualitative as well as quantitative information. The motivation for this project and the current level of fuzzy controls are described here, and some results from the most recent work on smooth switching of flight control modes using fuzzy rules are shown.

INTRODUCTION

The purpose of our paper is to describe the latest developments of, and motivation for a Sugeno Laboratory project leading to an intelligent semiautonomous unmanned helicopter. This project's goal, funded by the Japanese Government's Science and Technology Agency, is to develop a controller for an unmanned helicopter that can operate under environmental conditions considered too severe for a manned helicopter. For years now, fixed-wing unmanned 'drones' have been flown under severe and dangerous conditions, mostly in military applications. Unfortunately, fixed-wing aircraft cannot fly

into physically small and tight areas nor hover over a target; the helicopter, on the other hand, has the intrinsic ability to do both within limits.

A necessary and critical aspect of an unmanned helicopter is its remote control and mission requirements. For this project the remote control is to be achieved by using fuzzy control theory. Ultimately, our helicopter will incorporate voice activated commands through the use of natural language; for example: "Fly forward a little bit." The idea is that a relatively inexperienced remote operator can use natural language voice commands rather than a cryptic set of voice commands requiring months of training. These commands are naturally 'fuzzy' and hence fit into the fuzzy logic framework nicely.

The voice activated commands, however, are only part of the control problem. An equally important issue is the mission requirements. The unmanned helicopter must have a degree of autonomy for dealing with unforeseen situations like the collision avoidance problem. For example, in a situation where a volcano's eruption is predicted, a situation all too common in parts of the Pacific region, a geologist may wish to use an helicopter to place a sensor, or to take some rock sample, or to monitor an ever expanding lava dome inside of a volcano. Rock slides and some other threatening situations during a landing may go undetected by a human observer or an helicopter pilot until too late, whereas an autonomous unmanned helicopter, given the appropriate sensor suite, may be able to respond in time.

The control of an unmanned helicopter is not the primary issue here nor is it unsolved. It is well known that an helicopter is intrinsically unstable, complex, nonlinear, and time-varying; but helicopter designers, for quite some time now, have been able to control and stabilize helicopters very well with various linear and nonlinear control techniques. What we seek is an helicopter controller that can easily include qualitative as well as quantitative information.

Another aspect of this project reveals the methodology required to develop a sophisticated controller design by using fuzzy logic. Our helicopter problem is unique, in that we are now learning how fuzzy control techniques behave for systems with a high degree of cross-coupling. Furthermore, we are able to experimentally verify our methods in the field on an unmanned radio controlled Yamaha R-50 helicopter. The helicopter is a production model with an overall body length of 3.57 m, a rotor diameter of 3.0 m, 98cc gasoline engine, and a 20 kg payload.

THE HELICOPTER PROBLEM

The basic problem is to simply control the basic motions of the helicopter from "simple" hover flight to highly sophisticated maneuvering. This problem, as we shall soon learn the reason, is quite difficult to solve analytically. To fully grasp the difficulty of the problem, a brief review of some helicopter dynamics is necessary.

The helicopter has 6° of freedom in its motions:

- up/down,
- fore/aft (longitudinal motion),
- left/right (lateral motion),
- pitching,
- rolling, and
- yawing.

The motions of an helicopter are achieved by,

- collectively changing the pitch of all the main rotor blades, thus increasing rotor thrust (collective pitch),
- cyclically changing the pitch as a sinusoidal function of azimuth that tilts the tip-path-plane fore-aft or left-right and changes the thrust vector direction (cyclic pitch), and
- collectively changing the tail rotor pitch, which changes tail rotor thrust and thus the yaw moment.

An helicopter pilot must simultaneously control three forces and moments; a task that is almost impossible for any untrained human being. An helicopter pilot typically has at his disposal a cyclic stick to control both fore/aft motions (pitch control) and left/right motions (roll control), a collective lever to control up and down motions (vertical control), and pedals to control right and left yawing motions (yaw control). Lift, thrust, pitching, and rolling controls come from the main rotor while yawing control comes from the tail rotor.

The most significant problem with helicopter flight dynamics is that helicopters are inherently unstable or poorly damped systems. Their basic aircraft modes are cross-coupled without clear division of longitudinal and lateral-directional modes. Some dominant cross-couplings, for example, can be seen in forward flight. In forward flight,

the increase of the main rotor collective pitch and thrust increases load-on rotor; by increasing load-on the rotor causes rotor RPM to drop, thus engine fuel flow must increase to keep rotor in the required speed range. The increase of fuel flow increases torque on the fuselage, which means that tail rotor thrust must increase, the increase of tail rotor thrust varies the lateral force on the fuselage, thus the main rotor must vary the lateral tilt of rotor thrust to compensate, this causes the fuselage roll angle to change. In addition to the basic airframe rigid body dynamics, the rotor adds flapping dynamics, and the engine adds rotor speed dynamics. Furthermore, there are nonlinear variations in the dynamics with airspeed. Hence, control of an helicopter, although not impossible, is a difficult one indeed.

OUR SOLUTION

The solution for our helicopter control problem is through the use of the fuzzy control theory. The problem is not new, but the solution is new. What we want to achieve is an integrated control system that begins at a low level and ends at a sophisticated high-level supervisory control that takes as inputs natural language. The integrated approach is the key. The solution we have proposed and partially completed is a Fuzzy Hierarchical Control Design.

The Fuzzy Hierarchical Controller Design, as shown in Fig. 1 [omitted], is structured with several layers of ever increasing levels of control modes. The bottom of the upper layer (Flight Mode Management) contains the control modules for basic helicopter flight modes:

- Takeoff and Landing,
- Acceleration,
- Deceleration,
- Hover,
- Stop,
- Forward,
- Aft,
- Left,
- Right,
- Diagonal "Sideslip",
- Circling and Turning flights.

The flight mode manager's role is to manage the basic flight modes and to smoothly combine them. Each flight mode module uses a set of flight control primitives that are at the lower layer in separate submodules. These flight control primitives are the heart of the control system and maintain the correct pitch, collective, and stick positions for each flight mode in steady state or during transient states.

In addition to the flight manager, the upper layer also contains the parameter sets required for the control inputs, such as velocity and altitude set points, and control over coupling compensation. Finally, navigation and a command interpreter that assigns flight modes to the flight manager is at the top level of control. This level of control has yet to be implemented, hence the dotted lines. The fuzzy controller design is based upon three things:

- the qualitative idea of control—information gathered from an operations manual and interviews with a pilot;
- the structure of the controller—derived from kinematic knowledge of helicopter motion and a software simulator;
- the parameters for the controller—derived from field experiments.

These three items help us in developing linguistic rules for the helicopters flight modes. For Hovering for example, two typical linguistic rules are given by the following:

- If the body rolls right, then move the lateral stick leftward.
- If the body pitches forward, then move the longitudinal stick backward.

HELICOPTER HARDWARE/SOFTWARE

The helicopter has a set of sensors on board to measure angles, angular velocities, accelerations, velocities, and altitude; and as soon as we install a Global Positioning System, position measurements. The helicopter sensor measurements and control signals are currently passed to and from a personal computer (PC) through a 30 m umbilical cord. The PC is the fuzzy logic controller platform. An A/D-D/A converter is in the PC to sample the analog sensor measurements as well as to convert digital control signals from the fuzzy controller to the helicopter actuators. A new fuzzy controller to be placed on board the helicopter has been tested successfully. This controller is a specially designed board with four fuzzy inference chips made by OMRON.

Before field experiments can be done, new algorithms and techniques are first tested on an

helicopter flight simulator designed by Kawasaki Heavy Industries. The simulator, which runs on a Silicon Graphics IRIS workstation, is based on 3-D nonlinear differential equations, and it includes both atmospheric pressure (altitude effects) and wind effects. Unfortunately, the simulator cannot simulate takeoff and landings. Hence, we are restricted to start in hover mode. The fuzzy controller software for the simulator is written in C and is the same software used on the PC. The only difference is the input/output routines for data, I/O.

The production model helicopter has a standard radio-control (RC) unit that is common among RC hobbyist. The RC operator of the production model normally has to go through some months of training before he/she becomes proficient in operating the helicopter. In our case, the fuzzy controller operates in parallel with the RC unit. We use the RC unit as an emergency cutoff device or 'manual' operation.

FLIGHT MODE CONTROL DESIGN

At this time, all flight control modes mentioned in the previous section have been implemented and tested. Currently, our helicopter flies under fuzzy control through a combination of simple flight modes. It begins in hover mode and then either goes fore/aft or right/left. To change flight modes, for example from forward to leftward (90° sideslip) flight, the helicopter controller must first change to stop mode and then hover mode before it can change to leftward mode. These individual flight modes are always undergoing improvement to reduce the effects of drift, overshoot during stop mode, etc.

A model of the steady state\footnote control system for the helicopter is shown in Fig. 2 [omitted]. (The control loop is different for transient states.) The helicopter is modeled as a simple two-delay process that reflects the Newtonian laws governing velocities and displacement of a rigid body, otherwise we assume no model. The attitude and velocity state vectors from the helicopter are theta and x-dot, respectively. The control inputs are the error between the attitude/velocity state vectors and a set of reference set points, and, though not illustrated, the acceleration and angular velocity state vectors. A further component is in the controller that is called "trim" points to maintain the proper attitude required for a flight mode (Fig. 2 [omitted] shows the trim input, T_{longitude}, for maintaining the proper attitude in the longitudinal plane.)

As was mentioned before, the control primitives are the heart of the control system. These primitives interface directly with the control surfaces of an helicopter; for example, pitch of the main rotor blades. There are four basic flight primitives:

- collective,
- pedal,
- lateral, and
- longitudinal.

And, as the names imply, they control the helicopter's altitude, yawing, right/left, and fore/aft motions, respectively. Two of the primitives, collective and pedal, require only two sensor inputs each, whereas the lateral and longitudinal primitives require four inputs for control. Typically the inputs are the difference (or error) between the sensor data reading and a set-point variable, and the rate of change of that variable.

The yawing motion (pedal primitive) can be controlled by 9 rules. Each rule has two inputs, the heading angle error, e_{psi}, and the heading angle rate of change, psi-dot, and one output. The inputs take on linguistic values and the output is a singleton. For example, three of these rules are:

- psi-dot is Pos and e_{psi} is Pos, implies Pedal is Neg Big,
- psi-dot is Pos and e_{psi} is Zero, implies Pedal is Neg Medium,
- psi-dot is Pos and e_{psi} is Neg, implies Pedal is Zero,

where Pos and Neg denote positive and negative, respectively. The altitude (collective primitive) is controlled by nine rules and two inputs as well, the altitude error and the rate of climb. On the other hand, the fore/aft and left/right motions are governed by two factors, pitching/rolling angles and the lateral/longitudinal velocities. Hence, control is achieved by summing the outputs of two groups of nine rules; one to control pitching or rolling angles, and the other to control lateral or longitudinal velocities.

The rules are first constructed with the help of an helicopter pilot's experience and knowledge. Then the rules are tested and reformulated by using the helicopter simulator. The parameters in the rule base as well as the trim values are adjusted based on experimental data.

The purpose of the flight modes is to control the flight primitives in such a way that fore/aft motion or some other flight mode is achieved. This is done by passing the proper set points to each of the four control primitives. Furthermore, these set-point values must be updated for each new sensor sample. In the case of hover or stop modes, the set-point values are static and therefore the four primitives must simply maintain the set point. All the other modes include a velocity component that must be controlled separately to maintain a specific velocity. Velocity control is achieved through the use of nine rules and two inputs, error between the set point and actual velocity, and the acceleration—both in either lateral or longitudinal directions. The resultant fuzzy output controls either the lateral or longitudinal primitive's set points.

FUZZY FLIGHT MANAGER

The fuzzy flight control manager was conceived to smooth the transitions between flight modes, or smooth-mode changes. The idea is to take the crisp control outputs of the forward flight mode and the hover mode and combine them by using a rule base to achieve the desired flight mode. The mechanism to determine where or when the helicopter starts the flight transition is by way of preplanned points in 3-D space (waypoint) or by time. For example, consider the simple helicopter flight plan of flying from hover to a specific forward flight velocity, and then back to hover again. During forward flight (at some specified velocity) the degree for which the forward flight mode contributes to the flight controls is 100% whereas the hover mode contributes 0%. As the helicopter gets "close" to the way point, the helicopter must slowdown to avoid overshooting the way point. Now the degree of forward flight output is reduced to some fuzzy value, say 70%, while the degree of hover increases. As the helicopter approaches the way point, the hover mode contributes 100% of the controls, while the forward flight mode contributes 0%. Three of the rules may look like the following:

- If distance/time is small, then hover,
- If distance/time is medium, then 50% forward + 50% hover,
- If distance/time is big, then forward.

Hence the control signals to the actuators are derived from fuzzy weighting of the control outputs of two flight modes, hover and forward, i.e.,

$$\begin{bmatrix} P(t) \\ C(t) \\ L(t) \\ l(t) \end{bmatrix} = \begin{bmatrix} P_{hover(t)} & P_{forew(t)} \\ C_{hover(t)} & C_{forew(t)} \\ L_{hover(t)} & L_{forew(t)} \\ l_{hover(t)} & l_{forew(t)} \end{bmatrix} \begin{bmatrix} w_1(t) \\ w_2(t) \end{bmatrix}$$

where P is pedal, C is collective, L is lateral, l is longitudinal, and w_i are the weights given by the fuzzy rule-base. Here we choose to use singleton consequents for defuzzification.

Presently, the flight switching has only been tested between hover and forward flight modes. For switching between these two flight modes we only need one set of rules, because w_2 = 1.0 - w_1. As more flight modes are added, however, the above set of linear equations will have many more terms and will represent the general case. To illustrate the flight-mode transition, we present Fig. 3 [omitted], which shows the simulator results for velocity, distance, and weighting for transitions between hover-forward-hover-forward flight modes. A set of three rules (with triangular membership functions) based on distance between way points was chosen so that w_2 is 1.0 when distance is either medium or large.

Figure 3 shows [omitted], in dimensionless variables, how the weighting changes over time as well as showing the helicopter reaching the set-point velocity, 1.0, when the distance is far, 1.0. The first way-point from the origin, reached at about the 3700th sample, is twice the distance as the second way-point is from the first way-point. Hence, the distance is shown as 0.5. When the helicopter first begins its flight, the distance is large and therefore w_2 =1.0. Hence, the velocity increases until it reaches its set-point in about 600 samples, all the while distance is decreasing. At about the 1400th sample the rules start to decrease w_2 (and increase w_1 = 1.0 - w_2) at an exponential rate, thus decreasing the forward velocity. As the distance goes to zero, w_2 goes to 0.0 and the velocity therefore drops to a minimum value (this minimum is caused by drift.) At this point the new way-point is introduced at half the distance. As a result, the forward velocity increases quickly except that it never reaches its peak because of the shorter distance. This is

clear from the weight where it begins its roll-off immediately. Again the distance tends toward zero, the velocity drops, albeit at a slower rate.

Finally we would like to mention that the fore/aft and left/right modes can be simplified into one new flight mode called the Diagonal Flight Mode. The diagonal flight mode was originally conceived to fly with zero heading at a 45° angle, or 45° sideslip. However, it became clear that the four modes could be combined into one single mode with the addition of a crisp sideslip angle. This required the addition of another fuzzy velocity controller to control both fore/aft and left/right velocities. And through simple geometry, these velocities are weighted according to the angle of flight. Therefore the independent velocity controllers help to compensate for the coupling between lateral and longitudinal-directional modes, and in acceleration. In essence we have 'active compensation' during flight.

SUMMARY

In this paper we have only begun to describe the rather large effort and time that has gone into this fuzzy controlled unmanned helicopter project. We have described the motivation behind the project as well as an overview of the fuzzy controller design as it presently exists. Some typical linguistic rules were given to illustrate how we set about designing the controller. And finally, we showed some of our newest results in flight-mode switching.

What we have learned thus far is that a fuzzy hierarchical controller design can successfully control a highly coupled system with only qualitative information of the plant and without an explicit mathematical expression of the plant model. This does not mean that we designed the controller blindly without knowledge of basic physics, rather we have used our implicit knowledge of the physical laws of rigid bodies to guide us. It is clear that a highly coupled system can adequately be controlled with fuzzy control methods by combining independent fuzzy controllers for each cross-coupled mode.

ACKNOWLEDGMENT

We thank Dr. J. Fuller for his assistance and appreciate his input on the helicopter problem.
-- *David K. Kahaner, ONRASIA*

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AUSTRALIA'S MATHEMATICS IN INDUSTRY STUDY GROUP ACTIVITIES 10 May 1993

This report will be published in Vol. 20, No. 2 (June 1993) issue of the Australian Mathematical Society Gazette, and is distributed with permission of its authors, N. Barton and A. Guttmann. It is particularly interesting to see the success that this meeting format has had, and also to observe the importance of problems related to heavy industry and extractive technologies. I have made a few stylistic changes. [Comments by: D. K. Kahaner].

For further information, however, contact Dr. Barton at the following address.

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The Mathematics-in-Industry Study Group: 1984-1993, and Beyond,
N.G. Barton and A.J. Guttmann

Since 1984, CSIRO Division of Mathematics and Statistics has sponsored an annual Mathematics-in-Industry Study Group in association with academic mathematical groups. The outcome of the 1993 Study Group is described in this report. We also give a valedictory view of the concept from the CSIRO perspective. For the next 'three to five' years, the Department of Mathematics at the University of Melbourne will play the role formerly held by CSIRO.

INTRODUCTION

Since 1984, CSIRO Division of Mathematics and Statistics (dms) has sponsored the Mathematics-in-Industry Study Group—a problem identification and problem solving workshop. The nature of the Study Group has not changed markedly since its inception: it operates as a weeklong meeting to consider 5-8 industrial problems in need of mathematical research. The problems are identified in the months that precede the meeting of the Study Group, which is held in February, and technical reports on the problems are compiled into the

Proceedings of the meeting. The Proceedings are distributed free to all members of the Division of Applied Mathematics of the Australian Mathematical Society.

During the nine times that the meeting has been held since 1984, 63 problems from about 40 separate organizations have been presented. The Study Group has been held in collaboration with six separate universities in Australia and, on several occasions, the Division of Applied Mathematics of the Australian Mathematical Society has provided financial support.

The following goals of the Study Group have been unchanged for the last several years:

- To stimulate greater awareness in Australian industry of the need for and role of mathematics.
- To establish better links between industry and academic mathematicians.
- To provide improved university education of mathematicians through:
  - — expanded employment prospects for mathematics graduates,
  - — fresh research problems for mathematicians,
  - — innovative material for teaching courses.
- To provide Australian industry with high level mathematical advice on challenging problems, and
- To provide an opportunity for industrial scientists to receive expert training in mathematical modelling.

In October 1992, the Australian Mathematical Society Gazette included an article stating that CSIRO would sponsor the 1993 Study Group at the University of Melbourne, and that it would seek to identify academic groups to adopt the concept for 1994 and beyond. Since then, the 1993 Study Group has duly been held, and the Department of Mathematics at the University of Melbourne has undertaken the sponsorship of the Study Group for the next 'three to five' years.

In this article, the highlights of the 1993 meeting are given, CSIRO's views on the Study Group (1984-93) are summarized, and then the vision of the University of Melbourne for the continuation of the concept is presented.

THE 1993 STUDY GROUP

The 1993 Mathematics-in-Industry Study Group was held at the University of Melbourne, 15-19 February. The Steering Committee for the meeting included representatives from the dms, from the Departments of Mathematics at three universities (Melbourne, Swinburne and Monash), and from BHP Research.

Large-scale efforts were made to promote the meeting and to identify the topics that were considered. Seminars on the Study Group were given at five universities, a press release was sent to 64 media representatives, and a direct-mail notice was circulated to a mailing list of more than 3000 addresses. In addition, Digital Equipment Corporation and Australian Supercomputing Technology provided valuable marketing contacts. As a result, direct contact was made with more than 50 organizations, and five topics were eventually identified for consideration at the meeting.

The following topics were considered:

Statistical comparison of dragline buckets (BHP Australia Coal)

Draglines are exceptionally large machines used to remove overburden (or spoil) above coal in open cut mines. There are about 60 large draglines in Australia; each weighs thousands of tonnes and costs tens of millions of dollars. Typically, each dragline bucket holds about 100 tonnes of spoil. Small improvements in efficiency with their use lead to big savings.

BHP had data showing how long it took to fill various dragline buckets at various digging depths and radii. They wanted a statistically valid method for comparing the effectiveness of buckets, and this methodology was essentially developed during the meeting.

Optimal scheduling of dragline operations (Pacific Coal)

The problem of determining the optimum way to excavate overburden was presented by Pacific Coal. The variables that had to be considered included the width and depth of the excavations, and the strategies for moving the draglines around, whilst

the overburden was removed. A general framework for solving this problem was developed during the meeting of the Study Group. However, the work will require detailed follow-up with the client, before commercial benefits can be captured.

Simulation of filling of dragline buckets

In a third dragline problem, dms staff used a particle-based code to simulate the flow of granular material into dragline buckets of various types. The work convincingly demonstrated that the particle code can simulate how the buckets are filled, thereby leading to the possibility of improvements in design without the expense of building large physical models. Dms intends to pursue with vigor the further development and application of particle codes for this purpose.

Blending of lubricants (Shell Australia)

Shell asked for guidance in the fluid dynamics of how lubricant oils are blended in large (45,000 l) tanks. Blending is driven by a submerged jet, typically with a capacity of 1,000 l/min. Estimates of blending times were derived using prior knowledge of turbulent jets, and the results were confirmed by large-scale Computational Fluid Dynamics simulations using a commercial CFD code.

Stratification of molten steel in ladles (BHP Research)

As part of the steel-making process, molten steel is transported to continuous casters in large (approximately 200 tonne) ladles. Often the steel sits for tens of minutes in these ladles, during which time thermal stratification of the steel takes place. BHP have a CFD model of the stratification process, and asked for help in developing a simpler mathematical model that would explain the essential features. An appropriate model was developed at the meeting.

The short descriptions above hardly do justice to the detailed work that took place at the Study Group. For further details, see the full technical reports that have now been written for incorporation into the Proceedings of the meeting.

In association with the Study Group, we held a Student Technical Essay Competition on the innovative application of mathematics to industry. The competition attracted eight entries and sponsorship from Operations Research Group and Technology Index. The winning entry by Mr. Keith Briggs was titled "Modelling biological effects of electromagnetic radiation."

The Study Group generated useful publicity for mathematics. This included two major radio interviews, one feature article in the Financial Review, and a number of brief newspaper descriptions of the concept. In all, 110 delegates registered for the 1993 meeting.

RETROSPECTIVE VIEWS OF CSIRO ON THE STUDY GROUP

The Study Group represented a substantial investment by dms over many years. The benefits included:

- A much better knowledge of the mathematical needs by the Australian industry.
- The opportunity to promote the capabilities of mathematicians on a national stage.
- Collaborative activities between dms and academic mathematicians.
- Influence on applied mathematical research in Australia.
- Follow-up R&D by dms in some cases.
- Some international recognition of our work.

Academic participants would doubtless augment this list by direct educational and research benefits.

As seen from a dms perspective, the Study Group presented problems very successfully solved or generating new R&D. The following examples come readily to mind:

Problems that initiated new research: Two particular cases were the 1984 BHP/Mt Newman rock blasting problem and the 1985 ACIRL problem on crumbling of brittle material. Both problems led to significant papers in the international literature.

Problems of commercial significance: The 1985 Memtec problem was concerned with ultrafiltration, and the work eventually led to an international patent held by Memtec.

Problems that helped develop contacts with major industries: The best examples here are the series of problems from Comalco and from BHP. Dms now has wide-ranging and well-developed contacts with these companies, and the Study Group clearly played a useful role in this process.

Problems that generated follow-up R&D: The sound propagation problem proposed by the National Acoustic Laboratories at the 1985 meeting led directly to the funded development by dms of PC packages for sound propagation through the lower atmosphere. These packages are now nearly ready for commercialization.

Bright prospects: We anticipate successful outcomes from the recent particle code simulation of dragline buckets. Here 'success' includes securing funds for code development, and subsequent application of code to mineral processing equipment with concomitant economic benefits.

Academic delegates at the Study Groups have also used various problems in their personal research and in their course materials. It is noteworthy that an increasing number of presentations at the annual Applied Mathematics Conference in Australia follow directly from Study Group contacts.

Dms favors the Study Group concept to continue under the aegis of the Department of Mathematics of the University of Melbourne. We offer the following to the University in support of the Study Group in 1994 and beyond:

- advice on organization and marketing (mailing lists, who to contact, advertising, etc.,)
- supervision of one or two problems each year,
- guaranteed participation by experienced campaigners from dms,
- financial support, for example for travel and prizes.

VISION OF THE UNIVERSITY OF MELBOURNE

Having helped organize the 1993 Mathematics-in-Industry Study Group, and having been involved as participants in previous meetings, we, at the University of Melbourne, needed little convincing as to the value and importance of this activity. The Study Group has been a paradigm of academic/industrial cooperation in which the needs of both groups have been addressed, while each group has maintained its separate identity and integrity.

The benefits to industry, to CSIRO, and to university participants have been manifest; and it is our intention and desire to continue, and, if possible, to improve upon this successful formula.

To this end, Dr Kerry Landman has been appointed Director of the Study Group, and all comments, commendations, and complaints may be addressed to her at 'misg@mundoe.maths.mu.oz.au' or by facsimile on '+61 3 344 4599.' Dr. Landman was the person primarily responsible for the Melbourne University participation in the organization of the 1993 meeting. She has previously worked in a consulting capacity with SIROMATH, and has also had considerable consulting experience with industry in recent years.

Our intention is, in the first instance, to continue the successful formula of "piggy-backing" the meeting onto the Applied Mathematics Annual Conference—as far as the dictates of geography permit. To this end, discussions with the University of Newcastle are proceeding, with the hope that the 1994 Study Group will be held there in the week prior to the Applied Mathematics Annual Conference from 31 January to 4 February 1994. In 1995 and 1996 the Applied Mathematics Conference will be in Perth and New Zealand respectively, which does present problems, particularly for the industrial participants. It may be appropriate in those two years to split the locations of the Study Group and the Applied Mathematics Conference. Dr. Landman welcomes receiving your views on this matter.

Other concepts that have been raised include the formation of an appropriate Special Interest Group (SIG) of the Division, and greater involvement of computer manufacturers in providing computational facilities at the meetings. We intend to proceed slowly in these areas. The SIG requires a fairly precise Constitution and Articles, and with the Study Group in a state of flux, we would prefer to let it settle down before freezing the constitution—though the advantages of the SIG structure make it an attractive option for the future. Also the increased computational aspect has to be handled with care. An engineering workstation can comfortably support 1 or perhaps 2 users, thus is not completely appropriate for the group interaction of the Study Group. However, some problems do require intensive modelling, therefore, this aspect will need careful consideration. We desire the benefits of access to appropriate facilities without the alienation that could arise by virtue of a small number of users.

We are keen to see increased student involvement, and to have the Study Group more widely recognized by industrial users as a source of remarkably economical, yet highly effective consulting. To develop this recognition, Dr. Kerry will perform some follow-up with earlier participants to determine how they benefited from their involvement

with the Study Group, while keeping in mind how to shape an even more effective activity.

The Department of Mathematics and the Faculty of Science have agreed to provide the financial resources to support Dr. Landman in her role as Director for a period of three years in the first instance. As it has been the case previously, it is expected that the actual running costs of the meeting will be met by the fees paid by the industrial participants.

The Study Group has grown into an important element of the Australian Applied Mathematics scene in the past decade. Hopefully, it will continue to grow, and perhaps provide a springboard for Australian industry to take its R&D responsibilities as seriously as do our international competitors. If we manage to achieve even a small part of this, we will have provided an enormous benefit not only to our profession but to the nation as a whole.

On this stirring note, we invite you all to actively participate in the future of the Mathematics-in-Industry Study Group.

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SOFTWARE ACTIVITIES IN THE PHILIPPINES (1993)

A summary of software activities and related issues in the Philippines is given.

F. Kintanar

The following report was provided by D. K. Kahaner, but was prepared by:

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[I have not been to the Philippines and cannot verify the details of Kintanar's report. He graduated in Asian studies (history and anthropology of Indonesia, Thailand, and the Philippines from Cornell University), but shifted into software engineering about five years ago. He states that he has been involved "in Philippines politics and economic development since before I became a software developer, and I have also become engrossed with the development of industry and technology, especially hi-tech, in my suffering but struggling country." Of the following report, Kintanar writes that "I'm afraid I haven't supported my views with enough facts, but I think they are substantially correct."

For background: The Philippines is a country of over 60M people with 2.3% population growth, high-literacy rate (94%), but only US$835 per capita GNP, less than US$10B of annual exports but US$30B of foreign debt, over 8% annual inflation, and infant mortality of about 40 per thousand (approximately the same as Vietnam). DKK]

FROM KINTANAR...

Up to the late seventies, the computer industry in the Philippines consisted mainly of vendors for foreign hardware, and as a consequence a pool of systems engineers and programmers developed. Throughout the seventies, the Philippines was a leading site for offshore assembly of semiconductors (mainly ICs, and a number of Filipinos owned companies, many of which have since gone bankrupt.) So, there was a small cheap-labor-intensive, low-domestic-value-added electronics industry geared for export. By the early eighties, a few Filipinos programmers started selling data-processing programs abroad, and were very successful at it. Since then, the industry has been expanding at something like 50% a year (from an admittedly very small base). Last year's exports were reported to be about US$35M, but there could be significant underreporting (to avoid taxes, and from relatively small developers.) A Japanese-funded study estimated about 20,000 people with high-level training in computer sciences (equivalent to a B.S. in Computer Sciences), but, I suspect, many of them don't work in computer-related jobs. Many of those who do are in sales or administration. Probably a majority of those who program for a living do so in small consultancies for local clients who generally need dBASE or Clipper applications (and many of these people are self-taught, not included in the 20,000 with high-level training.) Perhaps only two to three thousand are programming for companies that export software.

About 30 of these export companies, (or maybe more by now, since I haven't been in Manila where most of these companies are based for the past three years;) and the largest have only about 300 programmers. Almost all of them are small start-up compa-

nies with little financial backing. The majority of their jobs are export contracts with some domestic contracts as well. And the majority of the export jobs are data-processing applications for minis and mainframes developed in Cobol or 4GLs.

At least one company, Software Brewers, has developed something more interesting: a CASE Tool package that runs on a PC and can generate code for mainframes. It also generates code for the PC, so you can test it on the PC. When I talked to somebody who helped develop it (this was about three years ago), he said that about 90 programmers were just working on this one project. The company's president would come up with many different ideas, have teams implement them, choose the best results for incorporation into the product and throw the rest away. It seems to me that this might indicate that the Philippines has a certain perverse comparative advantage for some types of software development. Software engineering manpower costs so little here that we can appoint dozens of people to solve a problem, have redundant development efforts, throw away a lot of the not so good results, and still come out ahead. Unlike the database application contract developers, who basically sell a service and get paid for their code only once, Software Brewers sell their product many times and amortize their development costs. They were able to get started because they linked up with foreign companies to distribute their product. I believe it has been marketed as 4GSA in the United States, Mozart in Europe, and AI Musashi in Japan. It is also being marketed (directly) in the Philippines as Super Daisys (or something like that.) Many other companies have talked about moving beyond contracting and going into software packages, but I don't know of any that have succeeded.

A number of foreign companies are also present with software development activities in the Philippines. Anderson Consulting has a large group, but probably they should be counted as local since they are an offshoot of SGV, in the Philippines (and perhaps Southeast Asia) such as leading accounting firms and the Arthur Anderson affiliate in the region. They use the methodology developed by Anderson Consulting to do contracts supplied by Anderson Consulting. The PACT group is European owned (French and maybe some other countries); Fujitsu has a group developing mainframe software. NEC, where I have been working for a bit over a year, set up a manufacturing facility for transmission equipment in Cebu, in mid 1989. It has a design engineering department with about 35 engineers designing telecommunications hardware, and about 55 people developing software, mostly to support telecommunications equipment. All engineers are hired straight out of college and are sent abroad for 6 to 9 months for training. About 1 to 4 of the software engineers are sent to the United States, the rest to Japan [! DKK].

The rapid growth of the software industry in the Philippines is all the more remarkable because of the usually critical state of the economy for the past ten years. The Philippines was already sliding into recession because of its chronic balance of payments problems, when the assassination of opposition leader Ninoy Aquino in August 1983, precipitated severe political and economic disruption. This helped to trigger a crisis in debt servicing, similar to that of Latin American countries. When Marcos was ousted in February 1986, there was a brief surge in the economy, but it was cut short by continuing balance of payments problems and a severe shortage of power-generating capacity. Because of the rather chaotic political and economic situation in the eighties, the Philippines missed out on the wave of foreign investment in Southeast Asia from Japan (and also Taiwan, and even Korea). In particular, after the devaluation of the yen in the mid-eighties, Japanese investment in Thailand and Malaysia surged, and their electronics assembly industries boomed along with semiconductor assembly. The Philippines semiconductor industry missed out on this and never really recovered from the downturn of 1984 because of the local economic difficulties. And, a substantial electronics assembly industry never really developed. (There is some, but compared to Thailand or Malaysia it is nothing.) As a result, the Philippines exports about US$9.7B a year, while Thailand exports about US$33B a year. And Taiwan is leaving us even farther behind (US$83B in exports.) In comparison to this "export gap", the contribution of the software industry in the Philippines is a drop in the bucket.

However, I like to think that the software industry is of particular significance, because it is mostly domestic value-added (other major export sectors have a big import component, such as semiconductors, electronics, and even garments, since our textile industry collapsed in the eighties) and is high-tech. Unfortunately, its future is not assured because of the poor quality of computer science education in the country's ailing university system. Very few departments have instructors with

graduate training, and many departments rely on their own recent graduates to pass on what they only recently learned from imported textbooks. Only four universities produce high-quality graduates (University of the Philippines Diliman, U.P. Los Banos, Ateneo, and De La Salle), and they are quickly absorbed by the local industry. Unfortunately, many soon leave for jobs abroad. Many other Filipinos with weaker university preparation manage to obtain software development skills, and many of them also leave for jobs abroad. However, those who stay behind do manage to keep the software industry going. Perhaps conditions will improve in the medium term; they won't improve in the short term, because the electric power grid in Luzon (the main island where Manila is situated along with 45% of the population) is experiencing 8-h daily power outages, and the situation probably won't be relieved this year.

I like to think that the economy in the Philippines has certain underlying strengths, and that if it overcomes some rather stubborn obstacles, it could perform as well as the economy in Thailand has for the past 15 years. However, the gap with our neighbors is growing rather than shrinking for the time being.

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INTERNATIONAL CONFERENCE ON SOLID STATE AND INTEGRATED CIRCUIT TECHNOLOGY (ICSICT '92)

This article highlights the work reported by researchers from China and other Pacific basin countries at the 1992 International Conference on Solid State and Integrated Circuit Technology, held in Beijing, during October 18-24, 1992. This triennial meeting, initiated in 1986, is a premier forum for disseminating activities in all facets of microelectronics, including semiconductor devices, circuits, materials and technology.

S. Ashok

INTRODUCTION

The International Conference on Solid State and Integrated Circuit Technology (ICSICT '92) was held at the 21st Century Hotel, Beijing, October 18-24, 1992. This conference was initiated in 1986 and has been held triennially since then. Covering all aspects of microelectronics, it has the potential to become an important forum in this part of the world as the Pacific basin gains widening influence in micro- and optoelectronics. About 300 scientists and engineers from 19 countries attended the meeting. There were 221 presentations scheduled in several parallel sessions, and the papers were winnowed out of a total submission of over 400.

The conference started with plenary lectures on global views of microelectronics, but from the vantage points of China, Japan, Taiwan, the United States, and Europe. The opening address was delivered by William J. Spencer of the SEMATECH industrial consortium, Austin, TX. He was also a General Cochair of the Conference, along with Li Zhizhian of Tsinghua University, Beijing. Spencer outlined the rejuvenation of semiconductor manufacturing technology development through industrial cooperation in the United States. Alluding to the Information Age we are in, he noted the millionfold improvement in the production of microelectronics between 1965 and 1985, and forecast another millionfold improvement in the next 20 years before physical limitations set in. He pointed out the gigacosts associated with the evolution towards nanotechnology, and stressed the need for a fundamental change in the semiconductor manufacturing process, with complete integration of manufacturing, modeling, and simulation.

The progress and perspective of microelectronic science and industry in China was given on behalf of Zeng Peiyan of the Ministry of Machinery and Electronic Industry. Applying the Confucian adage of 'One of thirty years old stands on his own feet' to IC technology, he described the extremely high priority given by China to make strong inroads into this mature field. He pointed out that IC research began modestly in China in the 1950s, but now has 23 research institutes with 15,000 technical personnel as well as 50,000 workers in the IC industry. He also discussed some of the accomplishments by Chinese researchers in the leading edge of microelectronic science and technology, and the ambitious plans laid out by the government of China for an eventual leadership role in this high technology.

The science and technology trends in Japan for advanced ULSI processing were addressed by M. Hirose of Hiroshima University. With the projected 1 Gigabit DRAM of year 2000 requiring 0.18 - 0.14 μm feature size, 50 nm junction depth, and 5 nm gate oxide thickness, he described the driving forces for investigation of in-situ surface cleaning, highly selective etching/deposition using innovative plasma-

assisted processes (e.g., low-temperature reactive ion etching, and digital etching), and in general the need for atomic scale control of Si surface reaction.

The strong emergence of the Taiwanese IC industry after years of expansion and evolution was described by Chintay Shih of the Industrial Technology Research Institute (ITRO), Hsinchu, Taiwan. According to Shih, the identification of ICs as a strategic industry and close interactions of industry, government, and the academia in Taiwan has helped catapult the country into a major IC producer (just behind South Korea). He described the two major national research projects; the Sub Micron Project, for 0.5 μm mass production of CMOS, and the National Nano Device Laboratory for development of low temperature, low damage, process/device module and reliability/feasibility studies. With the phenomenal growth in IC production and domestic market, it is expected that the Taiwan IC industry will rank fourth in the world production of ICs by 1996.

The microelectronic development perspective of the European community was presented by Roel Kramer of Philips Semiconductor International, Eintheoven, the Netherlands. While the know-how intensive aspect of the industry is suited very well to the demography of Europe, Europe's position in microelectronics has been rather modest, with equipment 'consumption' very low. However, given the high-strategic importance of the IC industry, the European Commission supports a variety of cooperative development programs (ESPRIT and JESSI, for example). Among specific initiatives where Europe has strengths are Digital Audio Broadcasting and Lithography.

The meeting, subsequently, proceeded on parallel sessions, dealing with the following principal topics:

- Semiconductor materials.
- Thin films and metallization.
- VLSI and advanced device technology.
- Characterization.
- Optoelectronics and compound semiconductors.
- Amorphous and polycrystalline silicon technology.
- Device physics.
- Reliability.
- Circuit design.
- Computer aided design and testing.
- Modeling and simulation.

This report summarizes the highlights of work presented by researchers from China and other countries of the Pacific. For brevity and focus, we concentrate on materials, devices, processing and device technology, and we exclude the last three topics that relate mostly to circuits.

SEMICONDUCTOR MATERIALS

The session on semiconductor materials, essentially Si, dealt with current developments such as silicon-on-insulator (SOI) and SiGe heterolayers, along with aspects of defects in Si crystals. Sun Maoyou et al. from the General Research Institute for Non-Ferrous Metals, Beijing presented their results on the use of an horizontal magnetic field to control the free-surface flow of Si in Czochralski (CZ) crystal growth. They found that a strong magnetic field dampens convection, causing oxygen in the surface melt to evaporate rapidly. This results in an overall reduction of oxygen content as well as lower values along the radius parallel to the field. The properties of N-O complexes in slightly N-doped CZ Si crystals were described in a joint paper from Wuhan University, Academia Sinica/Shanghai and Zhejiang University/Hongzhou. By using a new reduced pressure technique, they were able to incorporate N to concentrations as high as 10^{15}-10^{16} cm^{-3}. From T = 2 K far-IR measurements they were able to observe shallow donors related to the N-O complexes, and also more complex interactions of the nitrogen impurity under isochronal anneal in the temperature range 100 - 1100 °C. Li Wei et al. from the Hebei Institute of Technology reported on the mechanism of oxygen precipitation nucleation effects in CZ Si and intrinsic gettering (IG) effects in heavily Sb-doped Si. They found an optimal IG technique in n^+(Sb) substrates via a ramp anneal procedure.

The papers on SOI ranged from the use of zone melt recrystallization (ZMR) to direct wafer bonding. Zheng Peng-fei and Tsien Pei-hsin of the Tsingua University, Beijing, described their new technique of rapid RF-induced ZMR that makes use of their patented rapid thermal anneal system. They were able to obtain a high-scanning speed of 7-15 mm/sec, with minimal thermal damage such as melting and warping of the supporting wafer and total absence of Si agglomeration caused by poor wetting between the molten Si and SiO_2 below. Their colleagues from Tsingua (Li Yonghong et al.) presented an alternate approach for SOI, using

single laser scan of heated substrates. SOI technology using porous oxidized Si was studied by Huang Yiping et al. of Fudan University, Shanghai. As the Si dopant concentration critically determines the anodization threshold for surface porous Si formation, they determined that high-quality SOI structures can be obtained by oxidizing the porous Si in an $n^-/n^+/n^-$ configuration. Spike and wafer warpage problems are apparently minimized with this approach, and the breakdown voltage measured between isolated Si islands was over 250 V. A controlled thinning technology of bonded SOI with the use of a depletion layer as an etch stop was presented by a group from the Southeast University, Nanjing. The (p-type) Si film thickness obtained depends only on the doping level, and is independent of substrate orientation.

C.Y. Chang from the National Chiao Tung University, Taiwan, provided an overview of the potential of low-temperature epitaxy (< 500 °C) of SiGe on Si for realizing high-performance bipolar transistors, FETs, 1-12 μm IR detectors, multiple quantum wells, and disordered superlattices. He also described the 0.3 μm ULSI and SiGe epitaxy capabilities and research activities at the National Nano Device Laboratory located at Chiao Tung University.

THIN FILMS AND METALLIZATION

This session was dominated by papers dealing with selective metal deposition, silicides and metal-Si interdiffusion problems. In a lead-off paper, Wang Jitao of Fudan University, Shanghai, presented a so-called half-sealed structure model for a systematic explanation of the formation mechanisms of defects (wormholes, encroachment, etc.) and morphology in selective tungsten processes. In this model, a half-sealed structure forms at the edge of windows and under the pinhole of native oxide. The complex morphology and defects arise then from the varying local concentration of gases, especially tungsten subfluorides and HF, in these regions. Wang also presented experimental data to augment the model. On the technological side, a tungsten silicide process for gate contact and interconnect was described by a Zhu Zhongyun et al. from the Hua Jing Electronic Group, WuXi. They expect to use this technology for 1 MBit DRAM fabrication.

Refractory metal silicides were investigated by a group from the Peking University for application in Si Schottky diodes. Zhang Lichun et al. described the structural and electrical properties of $CoSi_2$, $CrSi_2$ and $TiSi_2$ Schottky diodes, and found them to have excellent thermal stability and the necessary breakdown performance for use in high-frequency power supplies. Epitaxial $CoSi_2$ growth on Si by non-UHV process involving rapid thermal treatment of a ternary Co/Ti/Si system was studied by a group from Fudan University. The formation and growth of an amorphous interlayer in refractory and rare Earth metals on Si systems by solid-state diffusion was investigated by L.J. Chen et al. of the National Tsing Hua University, Hsinchu, Taiwan. From extensive analytical characterization of a variety of interfaces (Ti, Zr, Hf, Nb, Ta, V, Cr, Mo, W and Y on Si) they found a linear (rather than diffusion-controlled) growth rate up to thicknesses of 30 nm, good correlations with metal-Si atomic size differences and critical and maximum amorphous interlayer thickness. P.H. Chang et al. from the neighboring National Chiao Tung University reported on the influence of Si and Cu 'dopants'—used to control Al spiking and electromigration—on the interactions between Al films and TiW diffusion barriers. From X-ray diffraction (XRD) and sheet resistance measurements, they were able to draw conclusions on the signature of Al-W compounds formed for different concentrations of Si and Cu in Al, as well as the rate of increase of sheet resistance in these doped Al films.

Other papers in the session related to the use of ion implantation for thin-film formation or modification. Silicide formation by ion implantation was investigated by Zhang Tonghe et al. of the Beijing Normal University. From RBS and XRD measurements of Ti and Y implants at 40 keV energy and 3 x 10^{17} cm^{-2} dose, they were able to detect uniform phases of mono- and disilicides, at target temperatures in the range of 300 - 550 °C. An interesting double implant technique for monitoring low-ion implant doses was described in a paper by Peng Jin of the Juajin Electronics Group, Jiangsu. Here, the low-dose B implant precedes a moderate dose B implant that has been annealed. It is found that reliable monitoring of the low-dose implant is possible by measuring the change in sheet resistance caused by the damage resulting from the latter. Cryogenic ion implantation and heavy-metal contamination removal for leakage current reduction in p-n junctions were explored by M. Takakura et al. of the Hiroshima University, Japan. As expected, they found one to two orders of magnitude reduction in leakage by minimizing metal contamination during

implantation. But the leakage current actually increased for implantation at -140 °C despite better crystallinity than under conventional room-temperature implantation. This is evidently due to the high density of trapped fluorine bonds in the low-temperature implanted Si.

VLSI AND ADVANCED DEVICE TECHNOLOGY

A large number of papers in this category belonged to various technological aspects of complementary MOS (CMOS), the driving force of current VLSI. E. Arai of NTT LSI Laboratory, Atsugi, Japan, started the session with future perspectives of Si technology beyond 0.5 μm. He pointed out the problems and solutions pertinent to hot carrier degradation of MOSFETs, electro- and stress-migration failure of interconnects, and rapid failure detection. He also reviewed the features of X-ray, e-beam and enhanced (phase shift mask) optical lithography. He stressed that future LSIs will have structures with a higher aspect ratio not merely for 3-D cells, but in every processing step. The major needs for the future evolution of VLSI technology are built-in reliability to offset complexity, development of precision inspection and measurement tools, and process cost control.

A multilevel metal HCMOS technology for high-density application specific integrated circuits (ASIC) was described by Zheng Yangshu and Zhang Min of the Shanghai Institute of Metallurgy. Their process involved sub-three micron design, with local oxidation of Si, full ion implantation, doped polysilicon films, and reactive ion etching (RIE). Yu Shan et al. from the Shaanxi Microelectronics Research Institute reported on their 0.5 μm CMOS IC technology using triple layer resist lithography, RIE, lightly doped drain (LDD), titanium salicide and multiple implants for the channel.

The use of ZrN as a new mask material for forming deep trenches with RIE was described by Zhang Lichin et al. of the Peking University. By using only a 50 nm thick ZrN mask, they were able to form 6 μm deep trenches in Si with nearly 90° sidewalls. Kang Shixiu of the University of Science and Technology, Hebei, reported on an investigation of resists for synchrotron-based X-ray lithography. It was found that three-component type resists (matrix, radiation sensitizer, and dissolution inhibitor) offer the best performance because of the ability to optimize each component optimally. Two such resists (RAY-PN and RAY-PF) were found to exhibit their superiority in resolution better than 0.3 μm and in speed ten times better than the conventional PMMA.

Improved tolerance of PMOSFETs to ionizing radiation was reported as a result of fluorine implantation into the gate oxide (30 keV F for 39 nm oxide thickness) in the dose range 4×10^{14} - 6×10^{15} cm^{-2} (Zhao Yuanfu et al., Li-Shan Microelectronics Institute, Shaanxi). The production of both oxide trap charges and interface states was suppressed by the F incorporation, specifically at the SiO_2/Si interface. S. Kar of the Indian Institute of Technology, Kanpur, presented his results of an investigation of atomic hydrogen passivation of ion implant damage in the Si MOS system. Dramatic restoration of MOS electrical characteristics towards those of the control device were obtained with nonoptimal, low-energy (<1 keV), room-temperature H implants. In contrast, post-metallization anneals (at 400 °C in H_2 ambient, for instance) which are quite effective in removing ionizing radiation damage and are totally ineffective in passivating displacement damage.

An ultrahigh vacuum-based nanostructure fabrication scheme for in-situ characterization and control of compound semiconductor fabrication and characterization was described by H. Hasegawa et al. of the Hokkaido University, Sapporo, Japan. Their molecular beam epitaxy (MBE) system incorporates a new photoluminescence-based surface-state spectroscopy system for characterization, and a Si MBE source for introducing an ultrathin Si interface layer on semiconductors such as InGaAs for control of Schottky barrier height by Fermi level unpinning.

H. Ishiwara of the Tokyo Institute of Technology presented an overview lecture on silicon on insulator (SOI) structures formed by heteroepitaxy. He reviewed the growth characteristics of fluoride and oxide insulator films on Si substrates, as well as the growth of semiconductor overlayers. Excellent Si films can be grown on oxide insulator films such as (Ba,Sr)O. He also showed that for the heteroepitaxial growth of Ge and GaAs electron beam exposure is effective in promoting both the crystallinity and morphology of the films.

The use of a stacked amorphous Si film to form poly-Si contacted shallow junctions with excellent diode characteristics (reverse leakage current <1 nA/cm^2 and nearly voltage-independent, forward ideality factor = 1.01 over 7 decades and activation energy of reverse current = 1.13 eV) was reported by S.L. Wu et al. of the National Chiao Tung

University, Hsinchu, Taiwan. C.T. Lin et al. from the same institution described an alternate approach to shallow junctions. They formed n^+-p junctions by implanting As through thin CoSi films and subjecting the wafer sequentially to a rapid thermal anneal and a conventional furnace anneal.

This session had also a number of papers dealing with new or improved device structures. T. Shibata of Tohoku University, Japan, described a new functional device—the so-called Neuron MOSFET (υMOS)— a multiple-input, weighted threshold device. It offers dramatic reduction in the number of transistors and interconnects (8 transistors for a full adder instead of the 50 needed in conventional CMOS), and it can also be *soft-wired* to change its logic function by external control signals. A notable implementation of υMOS is self-learning neural-network LSI using a low-power dissipation synapse device. A new photosensitive device was presented by Shi Zhongbin of Wuhan Microelectronic Technology Research Center. This gate-controlled modulation photodetector has the interesting feature of converting a DC light signal directly into an AC electrical signal. Another new device, detailed by Zhu Dazhong of Zhejiang University, Hangzhou, is a Si avalanche diode electron *emitter* for use in vacuum microelectronics. An (external) emission current of 0.1 μA was measured from a 5 μm dia prototype, and a 12 x 12 array has also been built by using self-aligned technology. Another group from Zhejiang presented a lateral channel field-control thyristor using V-groove etching, for possible use in power ICs and ASICs.

CHARACTERIZATION

The papers in this area fell in the domain of both materials and device interfaces. Examples of the former include the use of thermal wave technique, ellipsometry, Fourier transform infrared (FTIR) and He elastic recoil detection for studying specific material problems or characterize new phenomena. Liu Caichi et al. of the Hebei Institute of Technology studied vacancy clusters in neutron transmutation doped (NTD) Czochralski Si (Cz Si) using photo-induced transient spectroscopy and FTIR. Since NDT Cz Si is of considerable interest in power devices because of its high doping uniformity and internal gettering, a detailed study of the annealing regularities and irradiation defects is of great practical importance. Their colleagues from the same institute (Ren Ningyan et al.) reported on a Hall study of irradiation donor and new (thermal) donor in Cz Si.

The reports on interface characterization included a paper on oxide trap charge relaxation spectroscopy developed by Xu Mingzhen et al. of Peking University. By using the relaxation behavior of oxide traps and differential sampling techniques, they were able to develop a powerful tool for the study of high field conductivity and breakdown in thin SiO_2 layer. On the subject of GaAs surface passivation, there was a report by Wang Hai et al. of Fudan University, Shanghai, where they studied the $(NH_4)_2S$ passivation using XPS and Auger electron spectroscopy. The uniqueness of their study lies in the use of electron beam irradiation to promote the As-S bond.

A sensitive measurement technique for detecting ion implantation damage at doses below 10^{12} cm^{-2} in GaAs was described by Qiu Sujuan and Lin Qiquan of the Hebei Semiconductor Research Institute. They used the electron path pattern contrast resulting from the backscattering electron in channel backscattering spectroscopy. The electrons are scattered by phonons in a surface layer about 50 nm thick, and so the technique appears to be very effective for characterizing the crystal surface perfection.

OPTOELECTRONICS AND COMPOUND SEMICONDUCTORS

The papers in this session split rather evenly between material growth/processing and device applications. Researchers from the Semiconductor Institute, Academia Sinica, Beijing, presented papers on dislocations in MOVPE-grown AlGaAs/GaAs interfaces, and use of a low-temperature grown GaAs (LT GaAs) buffer layer to increase the electron mobility of a high-electron mobility transistor (HEMT) structure. Chen Peiyi et al. of Tsinghua Univeristy, Beijing, proposed and demonstrated a new dual-plane structure for monolithic integration of GaAs and Si devices. In this structure, GaAs layers are deposited on patterned Si substrates by MBE, and the GaAs devices are naturally isolated by the surrounding poly-GaAs (leakage current < 0.1 pA). Also, the interconnections between the Si and GaAs devices were formed through the vertical channels of single-crystalline GaAs. Wang Benzhong et al. of Jilin University reported on their metallorganic source modulation epitaxy (MOSME) for improving the crystal quality of lattice-

mismatched III-V structures. This heteroepitaxy technique depends on growing an interface layer by modulating the metallorganic source while keeping the flow rate of the group V source constant. They were able to grow high quality GaAs and InAs on InP substrates by using this method. A review of delta doping in MBE grown GaAs and related heterostructures was given by C.P. Lee of National Chiao Tung University, Hsinchu, Taiwan. He demonstrated that by combining delta doping with quantum wells, carrier profiles as narrow as 12 Å could be obtained. His TEM data show that Si delta doped samples have well defined dopant planes and no disturbances in epilayers and heterointerfaces, whereas Be distribution broadens because of surface segregation and aggregation.

A study of P/Be and Ar/Be coimplantation technology for InP optoelectronic ICs was described by a group from the Seoul National University, Korea (Chang Oh Jeong et al.). From a systematic variation of the coimplant species (P and Ar), they found that the Be activation efficiency was enhanced (up to 75 % in contrast to 32 % for Be single implantation) and in-diffusion minimized, principally by the ion damage. By using this technique they were able to fabricate fully ion implanted JFETs. Another reported work on ion implantation involved the use of B ions into n-type (Si-doped) GaAs for device isolation. Liu Yili et al. of the Beijing Normal University found that high resistivities can be obtained with anneal under certain conditions due to the formation of a $B_{Ga}Si_{As}$ complex that acts as an acceptor.

In the devices area, there was an interesting use of an MOVPE-grown $Ga_{0.5}In_{0.5}P$ disorder/order/disorder (DOD) structure for realizing a high-performance visible LED. M.K. Lee et al. from the National Sun Yat-Sen University, Kaohsiung, Taiwan, showed that the observed emission peak at 667 nm corresponded to the bandgap of the ordered active layer. The DOD structure is essentially equivalent to a double heterostructure, thus giving rise to light intensities several times stronger than those of equivalent homojunctions using either ordered or disordered layers. The realization of an integrated fan-shaped photodiode array for an optical multichannel analyzer (MCA) was described by Huang Youshu et al. from the University of Chongqing. The MCA is intended for applications in two-phase flows and catalysis. S.S. Lu and C.C. Wu from the National Taiwan University, Taipei, described their use of a 10 nm thick $Ga_{0.51}In_{0.49}P$ hole barrier in a GaAs bipolar transistor. They were able to obtain a current gain of 240 with an offset voltage of only 40 mV.

AMORPHOUS AND POLYCRYSTALLINE SILICON TECHNOLOGY

Large area microelectronics has come of age in recent years with the continual development of amorphous and polycrystalline thin films; the stakes being very high due to large scale applications such as flat panel displays and television. Hence, a session was organized around this field, and a number of papers were devoted to the matrix addressing element, viz., the thin-film transistor (TFT). The remaining papers addressed materials problems and other devices such as photodetectors.

Two papers from Peking University (Han Ruqi et al., and Lia Xiaoyan et al.) outlined the simulation programs they had developed for both the LCD pixel element and the amorphous Si TFT. Their model specifically accounts for the peculiarities of the hydrogenated amorphous Si (a-Si:H) MOSFET (relative to its crystalline Si counterpart), and also extends to a 2-D simulation for accurate analysis of various features such as charge and potential distribution, current-voltage and capacitance data, and breakdown voltage. The electrical properties of a-Si:H TFTs fabricated by a low-temperature plasma assisted CVD were studied by M.S. Feng et al. of the National Chiao Tung University, Hsinchu, Taiwan, as a function of deposition temperature. They found improvement in electrical performance with substrate temperature in both the gas and surface reaction regimes (over a range 150 - 330 °C), and correlated it with increase in the refractive index of the a-Si:H. The use of hydrogen and oxygen plasma on poly-Si TFTs was described by Horng Nan Chern et al. from the same university. While hydrogen plasma passivation of defects in Si is well known, their results suggest that oxygen plasma is also quite effective in improving the threshold voltage and subthreshold slope of the devices. Also, the oxygen plasma treated TFTs were found to have better thermal stability than the hydrogen plasma treated devices.

A new addressing scheme for the a-Si:H TFT active matrix was presented by Zou Xuecheng et al. of the Huazhong University, Wuhan. By using a three-level gate pulse and an additional a-Si:H ambipolar (i.e., one with both electron and hole

accumulation under positive and negative gate voltages, respectively) transistor, they were able to compensate the effects of parasitic capacitance. This scheme also gives rise to a new form of redundancy.

Among other devices, there was a new multilayer avalanche photodiode (APD) using an a-SiN:H/a-Si:H superlattice prepared by plasma enhanced CVD. Jiao Lihong et al. from the Nankai University reported their results on this structure, including effective impact ionization ratio (2.4 at 80 V) and excess noise factor (1.84). They see scope for further improvement by tailoring the composition of the nitride layer. Chen Kunji et al. from Nanjing University observed visible photoluminescence at room temperature from *crystallized* a-Si:H/a-SiN_x:H multiple quantum wells (MQW). From XRD and Raman spectroscopy they found the average crystallite size in the Si well layers to be about 35 Å, limited by the a-SiN_x:H barrier. Si-Chen Lee and Wen-Jyh Sah of the National Taiwan University, Taipei, demonstrated the feasibility of building a 16 x 16 four quadrant orientation detector they had invented for use in machine vision. By using a hollow structure, they were able to reduce the angle detection error when the contrast edge moves to the corner of the sensor.

Researchers from the Chinese Academy Sciences, Beijing, discussed their studies of a-Si:H stability problem (Staebler-Wronski effect) under multiple cycling. Kong Guangling and Sun Guosheng found a sharpening of the band tail and an ordering of the amorphous network under multiple cycling, and offered a microscopic mechanism to explain the behavior. Their colleagues Liao Xianbao et al. addressed the problem of interfacial contamination in a-Si:H solar cells by studying the p/i and n/i interfaces of the p-i-n solar cell with intentionally introduced contamination. From transport measurements as a function of temperature, they inferred the principal effect of the contamination to be anomalously high-potential barriers for holes.

DEVICE PHYSICS

The papers in this session were a variegated assortment, dealing with bipolar transistors, FETs, Schottky junctions, and variants of these devices. He Xiaoyang et al. from the Shanghai Institute of Metallurgy compared the room temperature and 77 K properties of high-performance Si bipolar transistors with theoretical predictions, and found that the β degradation at 77 K is mainly due to carrier freeze-out. Based on their results, they have proposed a new bipolar structure to make full use of polysilicon emitter and a narrow base bandgap. Y.C. Weng at al. presented a low-temperature device simulator developed at the National Taiwan University, Taipei, together with a device-level study on the performance of a CMOS differential amplifier operating at 77 K.

A review of thin oxide reliability physics was given by Ching-Hsiang Hsu and H.L. Hwang of the National Tsing-Hua University, Hsinchu, Taiwan. Long-term instabilities were traced to the presence of dangling and weak bonds in the oxide and at the oxide-silicon interface. It was held that replacing the H-Si bonds by Si-N or other stronger bonds could improve the gate oxide reliability. A paper that detailed the device physics research for submicron and deep submicron space microelectronic devices and ICs was presented by Huang Chang et al. of the Shaanxi Microelectronics Research Institute. Their goals are to achieve thin-film submicron SOS/CMOS devices, deep submicron lightly doped drain (LDD) CMOS ICs, and C and Ku band microwave GaAs MESFETs and HEMTs. The various device simulators that they were developing, were outlined in the presentation.

RELIABILITY

The papers in this session addressed issues such as gate oxide integrity, radiation damage, and electromigration. The possible perils of residual radiation damage arising from synchrotron X-ray lithography were reviewed by Ching-Hsiang Hsu of the National Tsing-Hua University, Hsinchu, Taiwan. Noting that X-ray damage generates positive charges, neutral traps and acceptor-like interface traps, he pointed out the need for different annealing techniques. While the reliability of the p-channel MOSFET is degraded by residual radiation damage, it is predicted that this effect would become insignificant as the devices scale down to 0.25 μm and below. The efficacy of SiO_2 prepared by pure water anodization for future MOS applications was studied by T.F. Hung et al. of the City Polytechnic of Hong Kong. They found highly symmetrical conduction peaks and smaller conductance peak losses than with thermal oxides, implying a more homogeneous trap cross-section and distribution in the anodic oxide.

From the University of Hong Kong, there was a paper on the recovery of mobility degradation in n-MOSFETs (Z.J. Ma et al.). The authors attribut-

ed the recovery to the neutralization of the trapped electrons in the gate oxide by subsequent hot hole injection when a high-drain voltage is applied to the degraded devices with the channel off. This mechanism also helps explain the larger mobility recovery observed in nitrided-oxide n-MOSFETs. In a companion paper, the authors showed that thermal nitridation of SiO_2 can radiation-harden the silicon/oxide interface, but also introduces hole traps. As a result, quite different device degradation behaviors are seen in the two oxides. The use of 1/f noise as a predictor of the reliability of subsurface Zener diodes was described by Zhuang Yiqi and Sun Qing of Xidian University, Xian. Their results show that an initial 1/f noise measurement may be used as a fast and nondestructive tool for reliable screening of these devices.

The conference was also highlighted by an evening panel discussion on the set-up of an IC facility in Shanghai.

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ASSEMBLY LINE AUTOMATION ACTIVITIES IN JAPAN, 11 MARCH 1993

Assembly line automation examples detailed at five Japanese companies.

David K. Kahaner

A very interesting article appeared in Nikkei Mechanical, 29 June 1992, providing a wealth of anecdotal examples of Japanese experiences in automating assembly-line operations. I hope that readers who are interested in production automation will find this useful, and I believe that even nonexperts will be impressed with the large number of small issues that must be confronted. The article begins with a general discussion of the issues and an overview of activities in five specific companies, Daikin (air conditioning), Gunma NEC (PCs), Caterpillar Mitsubishi (hydraulic shovels), Fujitsu (8-inch hard disk drives), and Seiko Epson (printers). Following this, efforts of each of the companies are presented in very readable but detailed text. I have freely cut and altered sections of the translation that appear not to be relevant.

ASSEMBLY-LINE AUTOMATION: "WE'VE COME THIS FAR"

INTRODUCTION

Now that it has become commonplace to automate production (fabrication) lines, the next step is the complete automation of assembly lines. This is being aggressively pursued in the Japanese semiconductor industry and segments of the household electrical goods industry. Small and medium-sized assembly lines and those where many models are assembled in small lots have yet to implement full automation, but even they are being challenged to do so.

Assembly lines that have begun to implement automation are in various stages in terms of the degree of automation, flexibility, and feedback to product design. Lines in which the assembly of existing products have been converted from hand-assembly to robot-assembly are called "first-generation" automated lines; lines that are automated to the extent that some product design changes can be made would be "second-generation" lines. And lines that are made with automation features that impact broadly on product design would then be called "third-generation" lines.

All assembly lines, however, irrespective of their "generation," are subject to all kinds of limitations and conditions when they are built. Of all of these, in that sense, we can say "We've come this far." In the following we examine some of these automated assembly lines at Daikin Industries (external commercial air conditioners), Gunma Nippon Electric (personal computers), New Caterpillar Mitsubishi (hydraulic shovels), Fujitsu (8-inch hard disk drives), and Seiko Epson (printers). Of these lines, only the printer assembly line had been previously automated; the other lines all employed manual assembly until very recently.

NEW DEVELOPMENTS IN AUTOMATION-ORIENTED DESIGN TECHNIQUES OVERCOME PRODUCTION AND DESIGN LIMITATIONS

Production automation has supported the cost competitiveness and high quality of Japanese manufactured goods. Recently, automation has become a mandatory component in dealing with labor shortages, the needs to improve the work environment, and the demands to implement company-wide CIM (computer integrated manufacturing).

The current focus is on automating the assembly line. This is distinct from (simpler case of) fabrication lines where systems need only be built to automate the conveyance of work to NC machine tools and the like. In assembly lines, robot hands

and jigs have to be adjusted to handle each part, thus making the feeding of parts and line control very complex.

Now that we have achieved so many advancements in FA (factory automation) equipment, production control, and computers, the building of automated assembly lines is no longer unusual. To date, however, most of this assembly automation has been focused either on high-volume production operations (household electrical goods, etc.) or on products that have relatively simple structures. These automation applications have not spread through the entire manufacturing industry, however, as has been the case with fabrication line automation.

WIDESPREAD ASSEMBLY AUTOMATION MADE MORE FEASIBLE BY 3 TECHNOLOGICAL ADVANCES

We discuss assembly automation applications at Daikin Industries (external commercial air conditioners), Gunma Nippon Electric (personal computers), New Caterpillar Mitsubishi (hydraulic shovels), Fujitsu (8-inch hard disk drives), and Seiko Epson (printers). Of these lines, only the printer assembly line had been previously automated; all the other lines employed manual assembly until very recently.

In these lines, products that are made in many different models must be assembled in small- and medium-sized lots and require high-precision assembly, and therefore making automation difficult. The pressure to automate these lines has mounted because of the labor shortages and demands to implement CIM.

Assembly automation applications have broadened, however, with the recent advances in production technology. They include robots and sensors, component feeding, line control, and production management. These advances are in evidence, for example, on the new printer assembly line, which Seiko Epson began operating in April 1992.

Seiko Epson succeeded in automating its assembly operations in 1984. But the company decided to refurbish its line in order to take advantage of subsequent developments in automated assembly technology. This decision also greatly influenced the design of the company's new printer models.

Specifically, what are these advances in automated assembly technology? We visited some of the latest automated lines in the country, and we noted advances in three major areas:

- positioning technology, which is fundamental to robotics,
- high-flexibility line construction technology that can cope with the mixed-flow production of multiple product models, and
- product design technology oriented toward assembly automation.

JIG, SENSOR POSITIONING KEY: MULTIPURPOSE USE OF VISUAL SENSORS

There is a problem that is common to all assembly automation, and that is positioning. Automation is relatively simple if parts can be neatly lined up and carried along, but the size and/or shape of a part often makes this impossible. There are other related problems such as the need to reposition parts like the large metal plates used in hydraulic shovels from which arise plate fabrication irregularities, or deformations in parts like the printed circuit boards in personal computers. It often happens that an assembly point will be out of position even though the end or edge of a part is properly positioned.

The first step in positioning is to develop jigs that match the parts. After a robot has taken up a part, first it has to place it on or in a jig before beginning to assemble it, and then grip it again. The position and attitude of the part is determined by the jig. With large metal plates, positioning is only possible after developing special jigs that can hold the plates in the proper position for assembly.

The shape of a part can make positioning with a jig difficult. It becomes necessary to use sensors to correct the movement of the robot. In many cases, however, accurate sensor detection is very difficult. A typical example of this kind of problem is seen in printboard warping. After having problems with printboard warping, Gunma Nippon developed a triangular measuring optical sensor that is used in a procedure to detect the height of three points on a printboard. A 2-D curving warp can be represented by three points, so the company had to come up with innovations in measurement point selection and interpolation techniques.

Visual sensor applications have now become somewhat standard. Visual sensors can detect the positions of all kinds of parts and are effective in implementing mixed-flow production operations. In addition to detecting positions, these sensors can also detect the shapes of parts, thus making them very useful in product quality control.

To be sure, the positional correction precision of a visual sensor is not all that great. When we factor the mechanical error of the robot with the limitations of image processing resolution, errors of several hundred microns can and do develop. More innovation is needed for high precision assembly.

In Daikin's air conditioner outdoor unit assembly line, visual sensors are combined with RCC (remote center compliance) mechanisms to perform high-precision nesting operations with compressor parts.

The compressors used by Daikin are scroll-type compressors that require approximately 10 μ precision in operations such as nesting crankshafts into bearings. Visual sensors alone do not afford this degree of precision, so the remaining error is absorbed by RCC mechanisms attached to the robot hands. The RCC mechanism contains an internal spring mechanism that makes it able to search for accurate nesting positions by the deflection of the spring by forces from the work.

MIXED-FLOW PRODUCTION FACILITATED BY MOVABLE JIGS & SENSORS SIMPLIFY PRODUCTION CONTROL

The assembly lines at New Caterpillar Mitsubishi and Daikin are interesting in that they are designed to cope with the demands of multiple-model, mixed-flow production. In order to make the assembly operation more flexible, movable jigs are employed to implement controls that are in accord with the part's shape. Visual sensors are also used.

In a mixed-flow assembly line, it is important to control information on product models so that the line operation can be changed to match the model moving on the line. Basically this information control is done by computer over a local area network (LAN), but methods are needed that are simpler and more reliable.

For this reason, Daikin has equipped all of its pallets with memory cards in an effort to achieve "object-information integration." Model information of parts dimensions and of detection standards is recorded, and then it is read at each assembly stage, so that the operation can be changed easily to accord with the model.

Daikin employs its own methods for line control and parts supply by using a sequence-synchronized production method for ordering the supply of parts assembled in the main work flow, and by attaching numbers to the work to indicate production order, so that parts can be ordered from the automated warehouse based on these numbers.

FOCUS ON MODULAR DESIGN: PARTS FABRICATION COSTS INCLUDED IN DESIGN

If assembly automation is approached merely from the perspective of production technology, however, problems are encountered in terms of equipment costs and reliability. For this reason, it has become standard practice to reevaluate product designs, and to implement design features compatible with automated assembly operations. It is thereby possible to simplify assembly and enhance operational reliability by, for example, orienting all the assembly steps in one direction or employing connection techniques amenable to automation.

To maximize the effectiveness of these measures, it is preferable to have "new lines for new models," developing parts concurrently with line construction. Due to problems of the product model change cycle and investment efficiency, however, a line often has to be automated for an existing model. A case in point is the hard disk drive line at Fujitsu.

In constructing its successful automated assembly line, Fujitsu took a fresh look at robot-based assembly sequences. The company also developed special supplemental mechanisms for complex assembly operations that could not be handled by robots alone. In addition, it implemented design changes in such details as screw shape.

Looking at recent trends in the design area, the modular approach adopted by Daikin in designing its air conditioner outdoor units is noteworthy. Product structures are divided into a number of modules for design purposes. Each module is assembled on a subline, and the assembly operations that are not amenable to automation are concentrated in the final assembly line. It is easy to achieve higher automation rates in the total assembly process because each module is designed to be compatible with automated assembly.

It is interesting to see that even automobiles are being modularized now in the effort to automate the final assembly process.

These product design techniques should change as assembly automation technology progresses further. The printer line at Seiko Epson is an extreme example of this. This company has, for some time now, been trying to implement unidirectional

parts assembly in order to facilitate assembly automation. Unidirectional assembly, however, translates into complex parts shapes and higher fabrication costs, so that the total manufacturing cost escalates even though assembly costs are low.

Now that robots have become highly functional, it is by no means difficult to insert a part diagonally. The best policy is to calculate parts fabrication costs and assembly costs to arrive at the most favorable method of assembly. Seiko Epson designed its new printers in the context of total manufacturing cost and then constructed its assembly line accordingly.

The task now is to improve the automation rate while developing ways to handle multiple-module, mixed-flow production. The mixed-flow production approach is effective in holding down equipment costs and coping with production fluctuations.

Key to implementing assembly automation is the development of designs compatible with them. This design-oriented approach is a new concept, however, but one with great potential. It should now become increasingly important to develop programs to coordinate design and production.

I. DAIKIN INDUSTRIES, LTD. AIR CONDITIONERS

ONE-BY-ONE MIXED-FLOW PRODUCTION OF 90 MODELS: AUTOMATION THAT REEVALUATES PRODUCT DESIGN

It is difficult to automate a mixed-flow production line for multiple product models. Not only must the robots be extremely flexible, but very sophisticated technology is needed for quality control.

In 1978, Daikin Industries implemented one-by-one mixed-flow production for its air conditioner outdoor units, and, since about 1985, has been working very hard to automate these production lines. These efforts bore fruit in March 1990, at the No. 2 plant at the company's Sakai manufacturing facility. This plant features integrated production of outdoor units for commercial air conditioning systems, and is capable of one-by-one mixed-flow production of 90 different outdoor unit models.

On the first floor of the No. 2 plant are lines for fabricating compressor scrolls, casings, and cores. On the second floor is a line for assembling the compressors and the outdoor units. Outdoor panel plating and painting lines are also housed on the second floor. Parts conveyance is almost completely automated by using an automated warehouse, elevators, and AGVs (unmanned transport vehicles). The compressor assembly operation is 90% automated and the outdoor unit assembly process is 30% automated. "In air conditioning, these are very high automation rates," (O. Abu, director of the Production Technology Center). Working two shifts a day, the plant is capable of turning out 800 units daily.

AUTOMATION-ORIENTED PRODUCT DESIGN: USING FEWER BOLTS IN COMPRESSORS

In constructing the No. 2 plant, Daikin developed new air conditioners. "If we try to automate with the existing product models, the line would become too complicated and equipment costs would be prohibitive," (Abu). This made it necessary to adopt product structures amenable to automated assembly.

To reduce the number of fastening operations in the compressor line, for example, the conventional method of bolt fastening was changed to shrink fitting and welding. More specifically, in installing rotors inside cylindrical steel casings and attaching rotors to crank shafts, Daikin adopted shrink fitting in which the parts are heated with a high-frequency current. And TIG (tungsten inert gas) welding was used in attaching bearing housings to casings. In this way the number of bolt fastenings was reduced from approximately 100 to 8.

FLEXIBILITY ENHANCED WITH VISUAL SENSORS: HIGH-PRECISION WITH RCCs

Daikin's compressor assembly line is made up of 29 steps that assemble parts in a cylindrical casing. These parts include a rotor, stator, crank shaft, upper and lower bearing housings, moving scroll, and stationary scroll. The line employs 13 robots and 10 automatic machines. Only three human employees work on the line by doing such manual jobs as connecting motor leads.

There are three basic sizes of compressors assembled on this line, but there is much diversity in the other parts, depending on the voltage specifications and anticorrosion structures. This requires great flexibility from the robots. The precision demanded is a high 10 μ.

To cope with these demands, Daikin employs sensors to enhance robot functions. A good example of this kind of application is seen in the robot that attaches ring-shaped Oldham connector to the

bearing housings welded to the body casing. A robot must adjust the center positions of the bearing housing and Oldham ring, exactly positioning a projection in the Oldham ring into a slot (Oldham slot) in the housing. The position of the Oldham slot differs from model to model. It is difficult to achieve the required precision with jigs alone; therefore, visual sensors are employed to detect the center positions of the bearing housings and Oldham slots. The positions are detected by using laser beams at three locations and then deriving the center position. The robot hand is equipped with a CCD (charge coupled device) camera and laser beam projector.

An error remains even after this, however, so the robot hand is further equipped with an RCC mechanism. This mechanism is able to search for the correct nesting position by means of distortions in an internal plate spring resulting from forces between the work. In this manner, delicate nesting operations can be performed with a high probability of success.

The RCC mechanism is attached to the robot through a spring mechanism that is equipped with a load sensor. When the nesting operation has not proceeded properly, the load sensor detects an overload and halts the attachment operation. This prevents the work from being damaged.

Robots equipped with visual sensors, RCC mechanisms, and load sensors are also used to attach the moving scrolls to the crank shafts. The visual sensors are used to detect the rotational positions of the crank shafts.

RCC mechanisms are also used on the robots that attach the stationary scroll to the body, and on the robot that inserts an oil line (2 mm in diameter x 115 mm in length) extending from the top of the casing into an oil hole.

The bolt-tightening robot hands are designed to handle work on equipment of different sizes. This robot positions bolts at four locations on the body of the compressor by using adhesion tools, and then it tightens the bolts in two operations by using two electric power tools. Since the interval between two bolt holes will differ depending on the size of the compressor's body, the interval between the two power tools can be adjusted automatically. The power tools are equipped with torque sensors to check the torque on the bolts. Innovations are also implemented in the robot that applies the manufacturing serial number to the compressors, after they have been assembled and the leak tests completed. A roll is sent out, a number is stenciled on for each unit, and the label is cut off and applied. Compared to making the labels off-line, this process is very simple.

AUTOMATIC IN-LINE PARTS INSPECTIONS: WRONG PARTS, ATTACHMENT ERRORS CHECKED

In addition to automating the assembly operations, it is also important to check, at the earliest possible stage, to see whether the unit has been correctly assembled. When trouble develops in an assembly step because of an error in the order of parts supply, the work then will not be passed along to subsequent steps. For this reason, Daikin implements stringent checks in the line, within the assembly operations, to detect parts supply or assembly errors. Examples of this are the prevention of scratches on or damage to the work using load sensors, and the detection of bolt tightening errors using torque sensors. Almost all of the other assembly steps also feature inspection functions. In the operation in which rotors are shrink-fitted to the body at the head of the line, work dimensions are *simultaneously measured to check* that the designated work has actually arrived. The robot hand and jig have built-in linear scales so that the outer diameter and height of the body and stator can be measured when handling the work.

The rotational torque on the motor and crank shaft, and airtightness, are checked in special inspection processes. The motor is checked at the step that follows the stator wiring hookup operation. A test rotor is inserted into the stator, the stator coil is powered up, and the direction of rotation is detected, thereby checking for mistakes in wiring connections. The inductance of the coil is measured at the same time to check whether the right stator has been installed. The rotational torque on the crank shaft is checked prior to nesting the upper casing, when the body assembly is nearly complete. The crank shaft is driven with a servo motor, the drive torque is measured with a torque sensor to determine whether the torque is within acceptable limits.

The leak inspection is conducted after all of the assembly operations are completed. Helium gas is sealed inside the body (casing), which is then placed in a vacuum chamber. Leaks can be found by detecting the helium concentration inside the chamber.

BASIC STRUCTURE MADE IN TWO MODULES TO RAISE AUTOMATION RATE

In designing the outdoor unit, efforts are made to use common parts in the various models, and to reduce the number of parts. An example of such efforts is seen in the heat exchanger, which is one of the main components in the outdoor unit. The fine radiators used to configure the heat exchanger are all made in the same shape so that differences in the capacity of the model can be adjusted with the radiators. The U pipe used to connect adjacent radiators is also standardized. Thus the need to change the way that the U pipes and other pipes are soldered is eliminated. Standardizing the fan motors used to cool the radiators in the various models is another example. This permits the cooling capacity of the 90 different models to be handled by only 6 different motors. Large differences in cooling capacity are handled by changing the number of motors used, while smaller differences are implemented by changing the type of motor.

The most interesting innovation is the introduction of the modularization into the design of the outdoor unit for the purpose of improving the automation rate. The outdoor unit has more parts in it than a compressor has, and each part is large and complex in shape. Accordingly, automating the assembly operation is very difficult. Daikin decided that the best approach would be to put the parts that could easily be automatically assembled into one module, and then assemble the system in modular units.

The two modules developed are the compressor module, which has the pipes installed on the compressor, and the heat exchanger module, which has the accumulators and cooling fan motors installed on the heat exchanger. Each of these two modules is assembled on a subline, then carried on AGVs to the final assembly line and then put together. The main operations performed on the final assembly line include the assembly of parts that cannot be assembled automatically (electrical components, pipe connections, etc.), and gas leak inspections and test runs, which are done manually.

AUTOMATING SOLDERING: DETECTING TEMPERATURE CHANGE WITH VISUAL SENSORS

The highest automation rate in the assembly of the outdoor unit is seen in the subline where the heat exchanger module is assembled. At the head of this line, the piping for the core of the heat exchanger is installed. First, the U pipes are inserted into holes opened in one end of the radiator pipes by a total of four robots. Then fine shunt pipes are inserted by hand to form coolant paths between the compressor and the indoor unit. The shunt pipes are made of soft copper, and it is very difficult for a robot to handle.

In the next step, the U pipes and shunt pipes are soldered by a robot. The robots that do this job have hands that are equipped with burners, a solder feed mechanism, and visual sensors. The portion of the pipe where the joint is to be made is brazed with the burner, and when the temperature becomes high enough, silver solder is applied. The visual sensors detect the changes in color of the area being soldered and therefore can detect the temperature at which soldering may begin.

Halogen gas is then pumped into the heat exchanger, and the airtightness is checked with gas sensors. This job is now done by hand but it will be roboticized in the near future. The robots will be equipped with gas sensors with which they will scan the soldered areas. Test operations have already begun. The completed heat exchangers are bent into an L shape with a coil bender, and further assembly work is performed on them as heat exchanger modules. More specifically, motors and accumulators are screwed to the heat exchangers, using frames, and then the fans are installed.

The objective of modularization is to automate this part of the process. When all of the parts are assembled on a single line, as conventionally, it is necessary to put the heat exchanger together while it is standing on a pallet. Motors and other parts must be attached from the side, thus making automation difficult.

With the modular approach, the heat exchangers are worked on while they are lying flat in a subassembly line. This makes it easy to automate parts installation. Currently, only the screw tightening job is being done by robots, and the parts handling is done manually. Daikin plans to begin doing all this handling by robots by spring 1993.

SUPPLYING PARTS BY SEQUENCE SYNCHRONIZATION: QUALITY CONTROL WITH ID CARDS

To implement one-by-one production, Daikin has adopted a production directive system at the No.

2 plant that is called sequence-synchronized production. In the production planning stage, parts are ordered so that they are accessed in the order called for by the model. In the production stage, production sequence numbers are applied to all pallets that move along the assembly line. These numbers are read automatically at each stage, and parts are supplied in the correct production order. In this manner, directives are given to fabrication lines, assembly lines, and plating and painting lines.

At the No. 2 plant, all work pallets that move along the production lines are equipped with "ID cards" that are used in production control and inspection operations. Each ID card has a memory capacity of 2 KBytes. This memory contains the model's specific information, such as the name of the model, work dimension data, inspection criteria, and robot and jig operating conditions. This model information is written in the ID card by the production control computer via a LAN just before the pallet is loaded onto the line.

One of the functions of the ID card is to control the work flow on the production line. The production control computer can monitor, in real time, what model is moving through what stage on what line. The ID card also has an important quality control function. Inspection criteria are read from the ID card at each stage, and it is compared to measured values to determine pass or fail. The inspection results are recorded on the ID card at each stage, and then they are gathered up by the production control computer in the final stage. Thus an inspection history is preserved for all products manufactured.

The ID card is also used for the purpose of enhancing production stage flexibility. Operations appropriate to each model can be executed by reading out operating conditions for the robots, jigs, and inspection devices from the ID card.

The automation modifications at the No. 2 plant are scheduled to be completed by March 1993. With few exceptions, these modifications are becoming operational on schedule. The next objective at Daikin is to automate the assembly of the indoor units. A new plant is scheduled for completion at the Shiga manufacturing facility in 1995 or so. This plant will contain an indoor unit assembly line that will be much more fully automated than the earlier lines. Like the outdoor units, the indoor units have a lot of parts but are much more subject to user demand in terms of design, thus making automation-oriented design difficult. Nevertheless, Daikin already sees its way clear to resolving these difficulties and intends to further extend the good results it has obtained, in terms of production technology, at the No. 2 plant at its Sakai facility.

II. GUNMA NIPPON ELECTRIC-PERSONAL COMPUTERS

Gunma Nippon Electric (Gunma NEC; head offices in Futoda City, Gunma Prefecture) is the main development and production center for personal computers carrying the NEC name. Gunma NEC built an automated assembly and inspection line for desktop PCs in November 1991. These computers represent some 10 million users. Some 1.17 million units were produced in 1991. But even at NEC, which has more than half the domestic share in this market, computers were assembled manually until 1991.

"We began planning the automated assembly line in 1987. But the plans were delayed when notebook PCs hit the market and raised the specter of declining desktop demand" (Masaki Takahashi, manager of the Systems Div. of CIM Systems Dept.). We may surmise from this that the biggest obstacle was return on investment. But what about problems in the area of production technology? Looking at the line, we see that a number of innovations have been implemented.

FLEXIBILITY FOR DEMAND SWINGS: MOVING AHEAD WITH PRODUCTION AUTOMATION

Gunma NEC is working with other parts of NEC to implement CIM. The aim is to achieve production and supply that follows market fluctuations. When a product sells well or poorly, the number of PCs produced may be flexibly increased or decreased accordingly.

To achieve this goal, Gunma NEC is seeking to shorten what it calls "production multiplier lead time." What this means is the time required to double the number of PCs that the company plans to produce. The idea is to take the time that fixes the production plan and set it to the actual number of product days, as nearly as possible. To do this requires a reevaluation of all the factors involved, from parts procurement to production systems. The parts problem can be dealt with by maintaining some degree of overstocking. As to the production systems, an excess production capacity should be maintained that represents 120% of the average

number of products shipped. Even these measures, however, are not sufficient to fully absorb fluctuations in PC demand. Thus the single-shift production operation, with normal 8-hour shifts, was modified to handle two or three shifts.

However, a problem arises, namely the retention of skilled personnel to man the shifts. Some 15 skilled workers are required to man a manual assembly line. Thus 30 must be retained to handle a double shift. But how can this be done when the extra workers are only needed during periods of increased production? The problem will be solved if production can be automated and unmanned production implemented. Gunma NEC is moving ahead with production automation. In 1988 the company automated packaging, and in 1989 automated the printboard assembly and inspection operations. In November of last year Gunma NEC built a robot line that automated the final assembly and product inspection stages.

REDUCING SKILLED WORKERS TO 1/3rd: SHORTENING TACT TIME BY 20 SECONDS

In the robot line mentioned above, there are 9 assembly operations covering a length of 50 m, and 12 inspection operations that cover 30 m, excluding the running test room. Four of the robots employed are 6-axis vertical articulated models, eight are 3-axis transverse models, one is a 2-axis transverse type, and two are horizontal articulated types; a total of 15 robots. The total investment was approximately Japanese¥500M. Of all the operations done on this robot line, only two assembly operations and three inspection operations are done manually. The two manual assembly operations involve hooking up cables. The cable assembly operations involve two aspects, namely plugging in the connectors, and stringing the cables. A job like stringing a pliable object like a cable is one of the most difficult for a robot to attempt.

Thus the robot line that was built has not completely eliminated manual labor, but it has reduced the number of skilled on-site workers required to just five. This is a 300% reduction over the manual line. At the risk of oversimplifying the situation, this automation has made it possible to take the same number of skilled workers from the manual line and spread them over three shifts on the robot line.

The tact time has been reduced by 20 s also, from 77 s on the manual line to 57 s on the robot line. The robot line can turn out 450 PCs in an 8-h shift.

ASSEMBLY SEQUENCE SAME AS MANUAL: COMPONENTS POSITIONED WITH SPECIAL JIGS

The robot line employs almost the same assembly sequence as the manual line does. The components that make up the PC are very few, included are only the base plate, U-shaped cover, front mask, rear cover, motherboard (on which the processor is mounted), floppy disk drives, and a few cables. And since the components making up the PC are so few, there is no need to change the sequence in which these parts are assembled. We will now describe this assembly operation.

First, the base is attached to a jig pallet, and the main printed circuit board (motherboard) is installed. The motherboard is screwed into place in the next operation.

Next a chassis for mounting the floppy disk drive is installed and the drive is mounted in it. A cable between the drive and motherboard is connected by hand. The expansion cage is then built-in and screwed to the floppy disk drive chassis, an expansion cage. A cable is then connected to the expansion cage. This connection is done by hand. The front mask is attached at the same time. The rear cover and top cover are then attached and screwed into place to complete the assembly. One interesting thing to note here in the assembly operations is the fact that all component positioning is done simultaneously prior to mounting any of them. The components are not small enough to be supplied by a vibrating parts feeder. For this reason the components are placed behind the robots on a pallet.

The components are taken from the pallet by the robots and placed in a special positioning jig. The jig positions the components with air-pressure cylinders. From the standpoint of tact time, the reasons for adopting a disadvantageous positioning method are as follows.

The method of using a pallet that can carry the components and perfectly position them involves prohibitive pallet fabrication costs. The operation of placing the components on the pallet then would also be problematic and impact negatively on component costs.

Next is the question of component precision. Most of the components used in a PC are fabricated from sheet metal.

Compared to machined parts, the precision of these fabricated units is poor, so that automated assembly cannot be done if the positioning is sloppy.

REEVALUATING DIMENSIONAL CRITERIA: HANDLING PRINTBOARD WARP

Even if components are positioned with jigs, this does not solve all the problems. Take the problems of screw-hole positioning precision and component warping, for instance. There are two general ways to deal with such problems. One is to measure the screw-hole position or warp and then adjust the movement of the robot accordingly. Another is to implement more exacting component precision.

The measurement approach requires longer tact times. The approach of more exacting precision requires higher component costs. These problems led Gunma NEC to reexamine the criteria for all of its components. A good example of what was done is seen in the motherboard. This is a big square printboard measuring 305mm^2. Conventionally, hole positions had been marked sequentially from one edge of the board. This yields decreasing precision as the distance from the edge to the hole increases.

When a printboard is secured in place, it is the relative position of one hole to another that is important, much more so than the relative position between a hole and the edge. This being so, beginning with the "PC9801 FA" series that went on sale January 1992, the design of the printboards was changed to indicate the positions of holes in terms of one standard hole located near the centerline. This eliminated the need to measure hole positions.

The problem of motherboard warping, however, could not be resolved by tinkering with the standard positions. Almost all the mounting and soldering of electronic components to the printboards have now been automated. The soldering is accomplished by wetting the printboards with molten solder. The heat from this process results in printboard warping. This cannot be avoided or prevented. And, since the motherboard is so large, a small angle of warp can result in displacements measurable in millimeters.

For this reason, at Gunma NEC, when printboards are positioned, the printboard warp is measured. This measurement is done with optical sensors using triangulation. Since there is no time to take measurements over the entire surface of the board, the warp is measured at three points simultaneously by three sensors. For this reason, mistakes are sometimes made in detecting warp. After the motherboard has been installed, it is inspected to see whether or not it is in the right position.

LINE MADE LONG FOR EASE OF MAINTENANCE: MANUAL ASSEMBLY ALSO POSSIBLE

One disadvantage in using a robot line is that it is longer than a manual assembly line. At Gunma NEC, the conventional manual assembly line is 40 m long, divided roughly equally between assembly stages and inspection stages. The robot line, however, is 80 m long, with 50 m for the assembly stages and 30 m for the inspection stages. In general, when production is roboticized, the line becomes longer. The reason for this is that robots have a hard time doing more than one thing. At Gumna NEC, each robot is set up to install two components. Even so, the robot line was twice the length of the manual line in the interest of maintenance. "We allowed plenty of extra space so that it would be easy to perform maintenance on it and revert to manual assembly in the event of a breakdown" (T Ono, manager of the Production Tech. Div. of the OA Dept.).

ADAPTABILITY TO MODEL CHANGES: EASIER TO ADD COMPONENTS

Another problem encountered when using automated robot lines is their limited adaptability when models change. A robot can be used to assemble all kinds of components if the program that controls the robot's actions is modified and the robot hand is tinkered with. If the number of components is increased however, a robot line is not very adaptable at all. If one does not wish to make the tact time long, one must install more robots. This approach not only is expensive in terms of equipment costs, it is also time-consuming. If it is permissible to lengthen the tact time, there is still the problem of how to supply the components when the number of components assembled by each robot is increased. The robot line at Gunma NEC is built so that it is easy to increase the number of components assembled by any one robot, thus making the line highly adaptable to production model changes. In general, a vertical articulated or horizontal articulated robot has a moving range of about 320°,

leaving a 40° arc through which the robot cannot move. This unreachable arc is usually positioned immediately behind the robot, and the track is made so as to reduce robot movement to the absolute minimum. More than two components, however, cannot be supplied to any one robot. Faced with this situation, Gunma NEC placed the unreachable arc on the right side of the robot. The track for assembling two components is not very efficient, but the types of components supplied can be easily increased. "It looks like there is a lot of waste in the robot track, but the tact time loss is less than 1 s," (Ono).

With this arrangement, besides the longer tact time required, there is the problem of having to frequently transport components from the component warehouse. This is because the component pallets have to be made small so that three of them each carrying different types of components can be placed behind one robot.

In practice, only ten components can be carried on one pallet. For this reason, the kind of carrier vehicle that moves over the floor cannot supply the components fast enough. At Gunma NEC, therefore, monorail transporters are used that have a maximum speed of 200 m/min, but are actually operated at 180 m/min.

HARMONIZING PEOPLE AND ROBOTS: MECHANICAL MODEL IDENTIFIER UNITS

With most robot lines, there are still operations along the way that have to be done by hand. The Gunma NEC line is no exception; five assembly/inspection operations are done manually. A number of different models are usually rolled along a robot assembly line.

For this reason, some kind of device is needed to detect which model has come along. If the models have different external appearances, it is easy for people to tell the difference. PCs look much the same, however, even though they are different models. At Gunma NEC, mechanisms are used that make it easy for either a person or a robot to identify a model. Bar codes and IC cards are widely used as the mechanism for model identification. Both of these methods are excellent for conveying information to robots, but they require a display device to make that information visible to a human.

The model identifier units adopted on the Gunma NEC line are mechanical devices. Each unit contains four reflector plates, with two sets of these attached to the jig pallet. The model is identified according to which of the four reflector plates on the right side comes out. The four plates on the left indicate how far the inspection process has gone toward completion. A robot can readily detect the presence or absence of a reflector plate by means of a light sensor, as can a human operator. The reflector plates can be caused to come out just by pressing a switch on the detector unit with an air cylinder. When the model-identifying reflector plates are brought onto the line, the number of reflector plates determined for that model is pushed out according to directives issued by the computer that controls the line. As to the inspection history, the reflector plates are pushed out at the point where the object passes a particular inspection stage.

Studies are being done on ways to do away with the cables that have to be hooked up by hand. If successful, this research should make it possible to achieve complete unmanned automation of assembly lines. Research has already begun, also, on ways to automate the assembly of notebook computers, which are much smaller than the desktop PCs and hence much harder to assemble automatically. Gunma NEC intends to employ robots in ways that will make it possible to adjust its production volume to demand vicissitudes.

III. NEW CATERPILLAR MITSUBISHI-HYDRAULIC SHOVELS

AUTOMATES LARGE-PART ASSEMBLY IN CONSTRUCTION EQUIPMENT: EFFECTIVE IN REDUCING MANPOWER NEEDS AND PRODUCTION STEPS

This is the first production line ever constructed that automates the assembly of large parts such as those used in construction machines. New Caterpillar Mitsubishi (head offices in Tokyo) uses computers in this automation implementation at its Akashi facility. The new assembly line, which employs 13 robots, went into operation assembling hydraulic shovels in July 1991. Some Japanese¥1.76B were invested in this line. With the start-up of this line, the assembly of the 20- to

30-ton class hydraulic shovels can now be done on one line instead of two. The number of workers employed on the assembly lines and in the warehouse was reduced from 99 to 38, and the assembly time (20-ton class) was cut sharply from 27 h to 9.5 h.

The two conventional lines turned out 440 shovels a month, whereas the one new line turns out 600. Product quality has improved 20%, based on reductions in the number of corrections that must be made when the unit comes off the line and the expense of responding to customer complaints.

IMPROVING PERFORMANCE, QUALITY, FLEXIBILITY: USE ACCUMULATED TECHNOLOGY

The company began designing the new line in July 1987. In 1986, the total number of hydraulic shovels produced was up 28% over 1985, putting pressure on the company to expand its production capacity. The existing lines were already 20 years old. So plans were laid for the new line. At the time, in addition to targeting improved productivity, the design team was determined to eliminate fabrication mistakes, improve product quality, and implement the flexibility necessary to build more than 450 different models in good time.

The medium-sized hydraulic shovels made on the new line were divided between two lines before, one line handling the 20- and 24-ton classes, and the other line the 30-ton class. Most of this work was done manually. As a result, there were a lot of assembly misses, such as forgetting to tighten bolts, failing to add water or oil in the right amounts, etc. With automation, these items are centrally controlled and product quality is stabilized. When the assembly work was divided between the two lines, the production volume for the 30-ton class shovels was low. It was just not possible to make the necessary investments to improve the 30-ton line, or to reduce costs. With the new line, using mixed-flow production, the line operating rate is expected to rise.

The project to build the new line began in October 1990. There were 16 people working on the project, eight on the actual assembly line, five on material flow, and three of information systems. The key technologies needed for the automation had already been developed on the conventional lines, however, before the project got started. Thanks to this accumulated technology, the new line could be built in just little over a year from the inception of the project.

FIVE UNMANNED STAGES ON ENTIRE LINE: BASE FRAME SUBLINE HELPS

The new line is made up of an automated warehouse, AGVs (automated ground vehicles) that supply the parts to the line, and three assembly sublines.

The assembly line is divided into two sublines, one for the upper and one for the upper frame: That is, one subline for assembling the upper swing frame and one for assembling the lower base frame. There is also a final subline for joining the two subassemblies together. The total length of the line is 187 m. The swing frame line is basically a continuous feed operation, while the base frame line is a tact feed operation. The tact pitch is 17 min.

The advantages of automation are more prominent on the base frame line. The swing frame line involves installing the engine, wiring, piping, and many other small parts, most of which must still be done by hand. There are very few people working on the base frame line. Of the five completely unmanned stages, three are on the base frame line. What must still be done by hand are the operations of inserting bolts in the track rollers (one person), tightening the travel drive (one person), inserting the idle wheel (one person), and hooking up the hydraulic lines (two persons). One line-keeper is also needed; a total of six persons.

The automated warehouse is equipped with 879 high racks for general parts and 192 kit racks for assorted parts, and it can accommodate parts weighing up to 1000 kg. Heavier parts are carried directly by AGV from the automated warehouse supply conveyor. Each AGV can carry up to 1500 kg and serve 36 stations. A total of seven AGVs are operated; six serve the swing frame line and one the base frame line. The automated warehouse and AGVs are very effective in the reduction of warehouse personnel.

VISUAL-SENSOR-BASED POSITIONING: CORRECTED VALUES FED BACK TO ROBOTS

On the base frame line, the rotary joint, track rollers, travel drive, idle wheel, and other parts are installed on the base frame, and the unit is greased. This line is 60 m long and comprises 11 assembly stages. A total of eight robots are employed on this

line, seven transverse coordinate robots and one transverse articulated type. The heaviest part installed weighs 500 kg. For this reason, many of the robots are shaped like automated cranes, and the vertical articulated robot is only used to carry parts weighing up to about 30 kg. Besides the robots, there are two inverting mechanisms and three bolt tighteners. Of the three bolt tighteners, however, one of the travel-drive tighteners is not used.

The first stage on the line is where the base frame is positioned. In implementing automation, it is very important to define the standards and criteria carefully. For this reason, the frames are positioned with special jigs that hold it at the four corners. Next, a six-axis articulated robot is used to place the rotary joint in the center of the frame. Bolts are supplied from the bottom and automatically tightened. The rotary joint is what connects the base frame to the hydraulic circuit of the swing frame.

After the rotary joint is installed on the frame, the latter is sent to the automatic inverter stage. There the frame is inverted 180 times so that the track rollers that guide the crawlers and keep them from coming off, can be attached. Seven or eight track rollers are placed on either side of the frame. A left and a right transverse coordinate robot automatically does this. Bolts are then inserted by hand, and another transverse coordinate robot tightens the bolts. After the track rollers are installed, the frame is turned over again, right side up, using the same kind of automatic machine that first inverted it.

The reinverted frame is then moved to the next stage, where the travel drive that drives the crawlers is installed at the back, and the idle wheel is installed at the front. The parts are carried automatically by a transverse coordinate robot, and everything up to travel drive insertion is automated. The idle wheel is inserted by hand. The hydraulic lines are then hooked up and assembly is complete. The unit is greased and painted at the next stage, and then sent to the final assembly subline.

AUTOMATION HINGES ON POSITIONING TECHNOLOGY: USING JIGS, VISUAL SENSORS

The key to successfully automating the assembly line was the positioning technology. "Metal plate structures have large inherent dimensional errors in them, so it is impossible to automate their assembly even if you mechanically position them," (Masaaki Ishii, manager of the Assembly Div. Mfg. Dept.). In addition to mechanically positioning the frames by using jigs, the company implemented a method whereby visual sensors are employed at each stage, as necessary, to feed back correction values to the robots. A special automatic machine does the initial positioning. At the back of the frame (which is loaded onto the line with a forklift), there is a hole for inserting the travel drive. The frame is positioned by two jigs, one that fits into the hole, and another that sandwiches it from the opposite side.

All of the stations are connected via fiber-optic LAN. The jigs are then moved by manipulation according to information from the central control room, and the frame is moved into the correct position. Visual sensors are used in installing the rotary joints and the track rollers. The rotary joint is installed by a six-axis vertical articulated robot equipped with CCD cameras. This robot is manufactured by Yasukawa Electric Manufacturing Co, Ltd. When the robot lifts the rotary joint and places it on the frame, the cameras recognize the installation holes, and facilitate accurate positioning. Then a tightening machine supplies bolts from below and automatically screws them in.

The visual sensors read two positions from among the 4 to 6 joint installation holes and adjust the positioning. This information is fed back to the tightening machine. Conventionally, bolts were first made hand-tight manually, and then a multiaxis tightening machine would tighten them. The torque on the bolts can also be monitored automatically, and this information is placed in an information file on the vehicle.

BOLT HOLES RECOGNIZED BY VISUAL SENSORS: FOUR ROBOTS INSTALL TRACK ROLLERS

Visual sensors are also used at the stage where the frame is turned upside down for the purpose of installing the track rollers. These track rollers are installed on either side of the frame. There are a minimum of seven and a maximum of eight rollers per side, depending on the model. Four-axis transverse coordinate robots on either side go into operation simultaneously; they carry the rollers one at a time from lineside and place them on the frame. After the guides are put in place, bolts are inserted at four locations by hand. These are automatically tightened by tightening machines, one on either side.

Each conveyor robot is equipped with two visual sensors, each of which read and recognize two bolt

holes on either side. The robot hand is controlled so that the center of the two holes matches the center of the track roller, and positioning is accomplished. The tightening machines are also four-axis robots, just like the conveyor robots, but they have no visual sensors, and perform positioning by using the correction values fed back to them from the conveyor robots.

Having gone to the trouble to automate the guide placement and tightening operations, it would be nice to automate the bolt placement operation also. But this is done by hand. The reason is because of problems connected with the production equipment and frame precision.

The problem relating to production equipment, more specifically, is that of the position of the conveyor robot. The rails are located 6 m above the floor, so the parts can only be lowered a maximum of 80 cm by the air cylinders. This involves a long stroke, so that parts are practically shaking as they come down. With the precision of the visual sensors down to 0.1 mm, this becomes a poor 1 mm by the time the parts are put into place. Unless the track rollers are jiggled around and positioned by hand, the bolts will not go in.

The other problem is that the holes are bored before the frame is welded together; therefore, there is variation in hole positioning from frame to frame. Something must be done to improve the frame hole positioning precision, such as boring the holes after welding the frame.

For reasons involving the tact pitch, visual sensors can only be used in doing the positioning the first time. After that, there is only the placement of the track rollers, at specified intervals, so the positioning will be even worse if the frame precision is poor.

To implement complete automation, including bolt placement, the company is now studying ways of improving the current frame precision of plus or minus 3 mm to plus or minus 0.5 mm, and of making the conveyor robots more rigid.

FOUR ROBOTS FOR CONVEYANCE, INSERTION: UNMANNED SUBASSEMBLY LINE

After the frame with the track rollers installed has been reinverted, it is moved on a conveyor to the stage where the travel drive is assembled. The subassembly line that continues from this stage on is unmanned. After the travel drive assembly stage comes the idle wheel assembly stage. No visual sensors are used in these stages, but three robots are used. These include transverse coordinate robots to carry the travel drive and idle wheel, and a gate robot used on the subassembly line.

Inside the travel drive are a hydraulic motor and a speed reducer. These components impart a turning force on the crawlers. The idle wheel is built into the front part of the frame, so internal springs act as crawler tensioners. The travel drive that is supplied via AGV is assembled on the subassembly line. A four-axis gate robot inserts a sprocket into the travel drive that is positioned longitudinally, after which a multishaft nut runner tightens the bolts. After it is assembled, the travel drive is inserted inside the frame from the side. For this reason, it is supplied by an automatic machine to the line in a sideways-facing attitude. This component is grasped by a four-axis transverse coordinate robot and inserted into the frame holes from the outside. The program is made so that this insertion action is accompanied by slight up and down movements. The bolts are inserted and tightened by workers.

This line is also equipped with bolt tightening machines just as the track roller assembly stage is. This bolt tightener, however, is not used, because it is too large, making it susceptible to interference with the frames and the robots. After going to the trouble and expense of installing this automatic bolt tightener, it is a shame not to use it. It will have to be made smaller and otherwise improved before the bolt tightening operation can be completely automated.

A four-axis transverse coordinate robot is also used in the stage where the idle wheel is installed in the front of the frame. This robot automatically conveys the idle wheel close to the frame, but then a human worker takes over and inserts the idle wheel into slots at the back of the frame by using a crane.

The hole into which the travel drive is inserted is round to make automation easy. The place where the idle wheel is inserted, however, is square, so that the idle wheel cannot be inserted simply with slight up and down movements, thus making automation difficult. After this stage, the hydraulic lines are installed, the upper part of the frame is automatically greased, and the base frame is transported to the final assembly line.

CALCULATING AUTOMATION RATE: EXCLUSIVE JOBS EVALUATED IN FIVE CATEGORIES

When New Caterpillar Mitsubishi planned the configuration of the new line, one of the most difficult things was the calculation of the automation rate. This rate is usually expressed as a percentage. However, there are three different ways to measure the value. One is to use the number of process steps (stages). The automation rate is then the percentage of total stages that have been automated. Another method is based on time. The automation rate is then the percentage of total assembly time that has been automated. And the third method is based on the number of workers who have been eliminated by the automation.

Representatives from the company visited some automobile plants to learn how they calculated the automation rate. But the automakers had not standardized their method of calculating this rate either, and each method used was flawed. When time is used as the basis for the calculation, for example, the assembly time (which is the denominator in the ratio) changes if the model is changed. This is a problem. The company therefore decided to break down all the operations into movements, and then divide the automation levels of these movements into five categories (levels). The levels of each stage are totaled and the average value is taken as the automation rate of the line. This is the technique that the company developed. Compared to the methods usually used, it evaluates the automation level of the jobs themselves, so it is easy to make comparisons because the jobs will not change even though the model does change.

In installing the travel drive, for example, prior to automation, the parts had to be carried with a crane. This is an automation level of No.1. In the new line, there is no stage for returning pallets after parts have been conveyed, so the automation level is up to No. 4. As a result, whereas the average value was 3 on the conventional line, it is up to 4.2 on the new line. If we use the number of stages to do the calculation, the automation rate is roughly 14% (five out of 35 stages are automated).

It was in the area of safety that it was difficult to harmonize robots and human workers. Not everything has been automated, so people are always involved in the operations. Photoelectric sensors are placed in various locations to keep large robots from becoming dangerous. If a person is in a passageway, for example, the robot cannot move.

No particular changes were made in the design of the shovels to facilitate automation, but production was rather designed to agree with the design standards of the Caterpillar Corporation in the United States. Nevertheless, the lower hole diameters are gradually being enlarged, and other design standards are being changed. These changes make it easier to insert bolts and the like, thereby facilitating automation. This assembly line achieved its production capacity target in about 5 months from the day it became operational. This success is owed in part to the steady labors that went on day after day behind the scenes to develop the technological details needed to implement assembly automation (sic). The results of these efforts are now visible in the stage where parts are assembled. In the stage where the speed reducer that is built into the travel drive is assembled, an experimental automation plant was built next to the production line. This experimental plant, which employ robots, is being used to work out problems involved in actual product assembly. This should translate into the smooth incorporation of automating devices into the line once the reliability of the devices has been established.

IV. FUJITSU-HARD DISK DRIVES MANUAL WORK VS HARD DRIVE ASSEMBLY: ALTERED SEQUENCE, INNOVATIVE SCREW SHAPE

Hard disk drives hate dust, grime, and other contaminants. When such foreign matter adheres to the surface of a disk it can cause malfunctions. Humans throw off a lot of foreign matter in the form of perspiration, dandruff, and the like. Thus human involvement in the assembly of hard drives impacts negatively on production yield. The level of skill of the worker, and even his or her state of health on a given day, can affect product quality. Hence automating the assembly of hard drives is an effective way to improve both yield and quality.

Fujitsu Ltd. has automated the final assembly line for its 8-in "Swallow" hard disk drives at its Nagano factory. The line has been operational since August 1991. The assembly is done in a class-100 clean room that is 3 m wide and 25 m long, and that is equipped with a number of robots and various special machines. The total length of the line is 20 m, which is short. What has been automated is the installation of the magnetic disks and the head assembly into a metal frame.

REDUCED SPACE, LOWERED COSTS, DEDICATED SYSTEMS

When building an assembly line, various restrictions and sanctions come into play, depending on the product being manufactured and management policy. A hard drive assembly line is no exception.

Hard disk drive development is a very competitive business. The useful lifespan of a drive is only about 2 years. Thus manufacturers are unwilling to spend a lot of money on equipment. Clean rooms are extremely expensive to construct. Thus it is very important to conserve space and keep these rooms small to keep costs down. The drives assembled at the Nagano plant are conventional devices that were designed with no thought of automated assembly. It is not possible to alter the basic structure of the product, so the method of assembly is limited. The main restrictions are discussed below.

When model changeovers and setup are considered, the ideal way to set up the line is to cellularize it by using robot cells that have the parts feeding mechanism and trays surrounding the robot built in. But redundancies between the robot cells lead to higher costs and require more space. If a nine-stage assembly line is to be built in a clean room that is 25 m long, the space for each stage will roughly be 2 m long. The length of a standard robot cell, however, is 2.5 m. Thus one may not employ the base-machine approach in which an assembly line is configured with combinations of robot cells. After considering all the limitations imposed, Fujitsu adopted the approach of building a special dedicated system for each stage and then connecting all the systems.

In the hard disk drive assembled on this line, the main components include a spindle assembly in which a number of disks are stacked at even intervals and fixed to an in-hub type spindle motor, an integrated actuator assembly in which there are a number of magnetic heads and an equal number of voice coil motors (VCMs), a frame, an upper frame cover, bushings that secure the spindle assembly to the frame, and covers for holes opened in the sides of the frame. When all the parts are assembled, with the interval between the magnetic heads in the actuator assembly and the disks in the spindle assembly maintained at approximately 0.2 μ, the drive is basically complete. The main key to success in precision assembly operations is in making the environment as clean as possible.

ASSEMBLING SPINDLE ASSEMBLY: INSERTING ALL DISKS AT ONCE

Fujitsu assembles the disk drives in seven steps (stages):

(1) Eight disks are stacked up, with spacers between them, and fixed as a unit to the spindle motor shaft (spindle assembly stage).
(2) The disks, fixed to the spindle motor, are mounted in the frame.
(3) The disks are turned and balanced.
(4) Servo signals are written to the disks.
(5) The head assembly is mounted in the frame.
(6) The upper cover is attached to the frame.

(Steps (1) through (6) each constitute one stage.)

(7) Inspections are performed (3 in number) for each of the preceding stages. All of the stages except (3) are automated.

The most noticeable thing about this line is that the sequence in which the spindle assembly is assembled has been changed to facilitate automation. The disks and ring shaped disk spacers are stacked up to the requisite number and then placed on the spindle motor shaft all at once. This is a fundamental departure from the conventional method of placing disks and spacers on the motor shaft one at a time. When the disks (and spacers) are loaded onto the spindle motor shaft, the inner surfaces of the disks (and spacers) rub against the shaft. This produces contaminants. With the conventional method, these contaminants drop onto the previously loaded disks and result in quality deterioration. Something was needed to be done in order to raise the quality of the drives further.

When the disks are loaded onto the shaft all at once, contaminants may be produced when the disks (and spacers) rub against the shaft, but those contaminants cannot fall onto the disk surfaces. The contaminants will settle downward, but will only collect at the bottom of the frame. It is conceivable that these contaminants will get swirled around and eventually find their way through the intervals between the disks and adhere to the disk surfaces, but there is little chance for that to happen. Hence, this approach will definitely result in improved product quality.

SUPPORTING UNDERSIDE WHILE PLACING DISKS ON SHAFT: CENTERING WITH TAPER

In assembling the spindle assembly, Fujitsu employs two robots, a stage that stacks the disks and spacers, an elevator mechanism that loads the disks on the shaft, a screw tightener, and other specialized equipment. The disk stacking stage has three poles erected on a round table. Each pole is positioned at the corners of an equilateral triangle. The disks and spacers are then stacked so that these poles pass through the center holes of the disks and spacers. The intervals between the poles are coordinated so that the poles do not chafe against the inner surfaces of the holes in the disks. The elevator mechanism used to load the disks has two arms, a cylinder to regulate the interval between the two arms, and a drive unit to move the two arms up and down. The disks are held so that they are supported from below by the two arms. In assembling the spindle assembly, one robot is used first to alternately stack up the disks and spacers. This robot has three cylindrical fingers. These fingers are inserted into the center holes in the disks (spacers) and then spread to firmly grip the disks (spacers). In this way the disks (spacers) are carried to the disk stacking stage and stacked.

When the requisite number of disks and spacers have been stacked, another robot takes the stacked disks and spacers and moves them, as a unit, to a position immediately above the spindle motor. The arm of this robot is equipped with three blue rod-shaped fingers. These long fingers are inserted into the holes in the stacked disks and spacers and then spread out to firmly grip the disks and spacers altogether. When the disks have been carried to a position directly above the spindle motor, the intervals between the fingers of the robot are contracted and the disks are loaded onto the arms of the elevator mechanism. The arms of the elevator mechanism are then slowly lowered and the disks and spacers are loaded onto the motor shaft by the force of gravity. Note that, even if some of the disks and spacers are not perfectly centered, they will be naturally lined up. The spindle motor shaft is tapered, so that the disks, which are only supported from below by the arms, can move freely until they are centered onto the shaft. Thus a complex operation is performed with a simple mechanism.

SCREWS ADAPTED TO AUTOMATION: INNOVATIVE SHAPES FOR SCREW HOLES, SCREW TIPS

Often automation can be greatly facilitated by making appropriate modifications in the design of the product. Fujitsu was unable to make any great changes in the designs of its existing product lines, but did implement 15 different slight design modifications without impairing product quality. The changes made in the shape of the screws used were particularly effective. In assembling the spindle assembly, when the disks are loaded onto the spindle motor shaft, the disks are fixed to the spindle shaft by using parts called clamp rings that are elastic. More specifically, a clamp ring is placed on the top of the stacked disks, and this clamp ring is secured with a number of screws to the spindle motor shaft.

During this operation, it is essential that the force used to tighten the screws on the clamp ring be uniform. If the tightening force is not even, the clamp ring will be distorted, and this will cause the disks to be tilted on the spindle shaft and result in a defective drive. This kind of defect occurs readily when the screws are tightened one at a time. For this reason, if these screws are tightened manually one at a time, an inspection stage must be added to check for disk tilt. When the screw tightening operation is automated, a number of screws can be tightened simultaneously. This makes it possible to fasten the clamp ring without tilting the disks. Fujitsu automated this operation and was able to eliminate the disk tilt inspection from the assembly line.

However, some problems had to be resolved before screw tightening could be automated. Fujitsu's problems included the following three.

(1) Screw tightening flaws occur when the positions of the screw holes get out of line.

(2) The driver bit would cut into the screw head and stop the line.

(3) The washers placed on the screws would come off while the screws were being supplied to the screw tightener.

Faced with these problems, Fujitsu changed the shapes of the screws. The screw shanks were tapered, for example, to accommodate errors in screw hole position. And the slots in the screw heads were changed from the conventional hexagonal (Allen)

and Phillips configurations to star-shaped holes. The screws were also modified to prevent the washers from slipping off.

In addition to the modifications in screw design, the screw hole diameters were enlarged from 4.3 and 4.5 mm to 4.8 mm. This was effective in preventing screw hole position shifts that result in screw tightening defects. And the inner diameter of the washers used was made smaller to keep the washers from slipping off the screws.

Fujitsu has thus successfully automated jobs on its hard disk drive assembly line that previously were thought to be very difficult to automate. This was done by altering the assembly sequence and making slight design changes. The company has also developed better ways to use its robots and specialized machines, performing complex tasks by combinations of simple movements. Because specialized machines have been used, however, it will be difficult to adapt to model changes and setup modifications. Enhancing the flexibility of the line is a task that the company now must work on. Fujitsu is currently building a new and improved version of the Nagano plant in Higashine City, Yamagta Prefecture.

V. SEIKO EPSON-PRINTERS

UNIDIRECTIONAL ASSEMBLY DEPRIORITIZED: DESIGN BURDEN LIGHTENED

In automating an assembly operation, it is very important that the design of the product be reconsidered. Products are typically designed or redesigned, for example, so that they can be assembled from one direction. Seiko Epson has been active in implementing such designs.

The company has 10 design concepts (criteria) that are used for the purpose of automating the assembly operations. One of the most important of these is the design that facilitates unidirectional assembly. The company has held to this concept since it built its robot line (called the "ET line") in 1984 for assembling printers. The 5th-generation ET line, built in April 1992, continues basically to reflect the unidirectional concept. Now, however, Seiko Epson is beginning to think differently about the ET line. Conventionally, the idea was for the design people to cater to the needs of the ET line. This is being replaced by the concept of acknowledging both sides (the ET line people and the design people) catering to each other's needs.

"We have not merely tried to make printers easier to assemble, but have sought to lower mold and die costs and component costs to reduce overall production costs," (Sachiharu Suda, Equip. FA Group at the Equip. Rationalization Cent. in the Printer Bus Dept. No. 1). In the past, much emphasis was placed on making assembly easier; this led to complex shaped components, and design became extremely difficult. Mold and die costs and component costs rose also. In the past, subassembly units were fabricated by other companies and then put together on the ET line. This could be done because "Seiko Epson could use all the know-how that we had accumulated during the course of many years' experience in using robots."

OLD LINE ROBOTS RELOCATED: TACT TIME CUT BY 10 PERCENT

The current ET line has a total of 53 stages (steps), including 38 assembly stages, 7 inspection stages, and 8 packaging stages. Only 5 of the assembly stages involve manual assembly operations. The remaining 33 assembly stages are all automated with the "SSR" series of transverse robots that were built by the company. The robots used are the same ones used on the 4th-generation ET line. The printer being assembled on this line is the LQ100 export model. The tact time has been reduced to 27.2 s, a 10% improvement over the 4th-generation ET line. The robots are the same as those in the 4th-generation line, so this is a significant improvement considering the fact that none of the design features were forced in the interest of ease of assembly.

The LQ100 printer is made of a rubber platen (which functions both as the print plate and paper feeder), a print header chassis that holds the drive mechanism for the platerboard print head, a control board, and a cover. In the assembly operation, the platen and print head are installed in the chassis, this unit is attached to a bottom cover, and the printboards are installed. The assembly operations are carried out on special assembly jigs. Three kinds of jigs are used, namely, one for assembling the chassis unit one for adjusting the print head, and one for ir .alling the printboards. The components supplied at the various stages are all carried by an unmanned vehicle. Vibrating parts feeders are used to supply small component to the assembly robots, while large components are supplied on the pallets.

GUIDE SHAFTS PASSED THROUGH HOLES: MOTOR INSTALLED FROM BOTTOM

What kind of design do you get when you seek to implement unidirectional assembly? Let us look, for example, at the VP550 model printer that was assembled on the 4th generation ET line. The housing was made with a U-shaped cut-out so that the platen and print head could be installed merely by dropping the carriage carrying them down onto guide shafts. If the platen and the guide shafts are not parallel, print quality is impaired. For this reason, the housing was made as a three-sided (horseshoe-shaped) extrusion-molded part. The method of simply assembling three panels involves the trouble of monitoring the assembly precision in addition to the parts precision. At best, a housing is a large part that must necessarily be of a complex structure. The U-shaped cut-out has no rigidity, so ribs or other reinforcing structures become necessary. The unit becomes extremely difficult to design in such a way as to facilitate automated assembly.

By way of contrast, the LQ100 housing is assembled from a chassis made of sheet metal and two extrusion-molded side frames. When the chassis and the side frames are assembled, precision is maintained by using a special positioning jig to keep the robot in the right position. The guide shafts are structured so as to pass through holes in the side frames. This is due to the need to strengthen the side frames. For this reason, the assembly is performed while the guide shafts are inclined. This is the result of efforts to balance ease of design and component costs against the difficulties of assembly.

This same principle applies to the step motor that drives the print head. In the VP550 model, this was attached to the front of the housing. In the LQ100, it is attached to the back of the chassis. Hence, in some respects, the unidirectional assembly concept is not slavishly followed. Some manufacturers like Seiko Epson that are in the vanguard of robot utilization are now moving in the direction of lightening the burdens placed on the design people.

AUTOMATING SUBASSEMBLY LINES: UNBURDENING AFFILIATED COMPANY

The VP-550 is a prime example of a product that was designed for ease of automated assembly. Even so, in some ways it was still difficult to assembly by robot. A good example of such difficulty was the carriage that carried the print head.

Guide shafts were passed through the carriage and then moved from side to side by a timing belt. The carriage had holes through which the guide shafts were passed, and these holes were equipped with rectangular pads impregnated with a lubricant to make the guide shafts slide more easily. When the guide shafts were inserted by a robot, the pad got wadded up, and things got out of position. The pads were positioned above the guide shafts, so that the lubricant would get smeared all over the shafts. Measures had to be taken to keep the pads from failing during the assembly process. If the pads were bonded to the carriage these problems would be fairly well resolved, but this would jack up the price of the carriage. For this reason, the assembling of the carriage and the guide shafts had to be done mostly by hand. The job of passing the guide shafts through the carriages was commissioned to an affiliated company, moreover, because that was less expensive than doing the assembly in-house by hand.

The outside commissioning of the assembling of units that are not amenable to robot lines is commonly done. But, this not only involves the additional expense of having the work done outside, it also reduces the efficiency of loading the units on the parts pallets and involves transportation costs as well. This outside commissioning of work that is difficult to roboticize, however, is rather like sweeping the problem under the rug. In building the 5th-generation ET line, Seiko Epson took another look at the units it had been commissioning out to other companies. The basic criteria was of course that of how to best minimize total assembly costs. The company decided not to change its design, but rather to roboticize the assembly of the guide shafts and carriages.

If the assembling of the guide shafts and carriage were to be done on a subline, however, it would create its own problems, such as requiring additional robots and taking up more floor space for installing the separate robot line. The company therefore decided to have the robots that assembled the carriage unit also take on the job of assembling the carriage and the guide shafts. What Seiko Epson did then was to add a jig to this stage for the purpose of temporarily holding the carriage. The carriage is placed upside-down so that the pads will not fall. Then, after the guide shafts are passed through, it is inverted, thereby implementing a slightly altered assembly sequence.

AUTOMATED POWER CABLE HOOK-UP: POSITIONING WITH HAND PRESSURE

Even Seiko Epson installs cables manually. Nevertheless, the company has successfully roboticized the installation of the power cables. When the power cables come onto the line, they are on pallets, soldered onto printed-circuit power boards. The power cables, moreover, are equipped with clasp that hold the cables to the covers. The robot has three hands, one to grasp the power board, one to grasp the power cable, and one to grasp the clasp. The power board and the clasp are pushed inside the cover and the power cable is placed in the position assigned to it.

The problem that arises during this operation is power cable twisting. If the power cable twists, the clasp will rise up in the pallet, thus preventing the robot hand from grasping it in the right orientation and making it impossible to attach the clasp to the cover. One way to solve this problem would be to reposition the components with a jig after they are taken off the pallet, but this involves too much tact time. Therefore, the hand was given new shape so that it would first push down on the clasp and then grasp it. By pushing down on it, the rising up of the clasp is corrected. "We experimented with more than five hand shapes and ways of pushing before we found the right combination," (Suda).

The ET line gives us a glimpse of a new trend in which production technology supports design technology. It should be noted also that the same robots are used that were used on the old line. When seeking to shorten tact times, the usual practice is to bring in new robots that move faster. Seiko Epson boasts outstanding robotics technology, but is currently perplexed by the problems involved in supplying components to the ET line from the automated warehouse. Like the robots, the automated warehouse and the unmanned transport vehicles are the same ones that were employed on the old line. Thus, the component supplying capabilities are the same as those used in the old line. As a result of shortening the tact time on the ET line, there is now a danger of not being able to supply the parts fast enough. "Our calculations indicated that we could supply the components fast enough." At each stage, the number of remaining parts pallets is ascertained, and parts supply requests are issued. Therefore, supply requests are sometimes issued simultaneously from a number of stages. As a result the automated warehouse cannot get the parts out on time. The company is currently working on ways to resolve the problem by having the supply requests issued ahead of time and reevaluating the location management system employed in the automated warehouse.

Dr. David K. Kahaner joined the staff of the Office of Naval Research Asian Office as a specialist in scientific computing in November 1989. He obtained his Ph.D. in applied mathematics from Stevens Institute of Technology in 1968. From 1978 until 1989 Dr. Kahaner was a group leader in the Center for Computing and Applied Mathematics at the National Institute of Standards and Technology, formerly the National Bureau of Standards. He was responsible for scientific software development on both large and small computers. From 1968 until 1979 he was in the Computing Division at Los Alamos National Laboratory. Dr. Kahaner is the author of two books and more than 50 research papers. He also edits a column on scientific applications of computers for the Society of Industrial and Applied Mathematics. His major research interests are in the development of algorithms and associated software. His programs for solution of differential equations, evaluation of integrals, random numbers, and others are used world-wide in many scientific computing laboratories. Dr. Kahaner's electronic mail address is: kahaner@xroads.cc.u-tokyo.ac.jp.

ULTIMATE MECHATRONICS PROJECT & KANAGAWA ACADEMY OF SCIENCE AND TECHNOLOGY, 16 MARCH 1993

A description of the Kanagawa Academy of Science and Technology and especially the Ultimate Mechatronics Project is presented.

David K. Kahaner

Kanagawa Prefecture is a busy industrial region that includes Yokohama, Kawasaki, Odawara and other cities, and it is Tokyo's southern neighbor. It houses over 850 research institutions, including almost 750 private research labs, 70 university labs, and 40 public research labs where over 50,000 researchers work. Almost all the major Japanese electronic facilities have a location in the Prefecture with giant sites for NEC, Fujitsu, etc. To take advantage of the location, the Kanagawa Science Park (KSP) was founded several years ago. Four large high tech buildings are attached star-like from a central core. KSP has its own hotel and conference facilities. The KSP serves as a focus for science and technology activities in the Prefecture. Most of KSP space is leased to private organizations, and the staff of these organizations use the location for easy access to the other nearby industrial labs.

KSP occupies three floors, two for labs and one for administration. It is the Kanagawa Academy of Sciences (KAST), a nonprofit research organization established by the Kanagawa Prefectural government in 1987. KAST has three main functions.

- Research
- Education
- Exchange activities, both domestic and international

KAST's budget is about Japanese¥2.6B per year. Of this amount, about 77% supports research, 8.4% is for educational activities, 6.4% for exchange programs, and 8.2% for administrative expenses.

Educational activities are mostly of "short course" type; two dozen of these courses were given in 1992, along with lectures, seminars, and visits to facilities.

Exchange activities involve grants for appropriate research themes (up to about Japanese¥5M), meeting support (up to Japanese¥2M for international meetings), the KAST Journal, and an International Science and Technology Symposium.

Although I had been to KSP several times before, it had been for other purposes. This time I went to KAST to hear about it generally and to speak to Prof. T. Higuchi, who spends his time between KAST and his position at the University of Tokyo,

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KAST Research Projects

(1) *Ultimate Molecular Spectroscopy*—(Leader: Hiro-o Hamaguchi). The primary objective of this

research project is to develop new spectroscopic principles and methods that are capable of revealing unknown molecular phenomena that occur under "ultimate" circumstances, e.g., ultrafast molecular change (within one-trillionth s). It is hoped that these new principles and methods eventually will lead to the development of a variety of new material sciences and new technologies based on them. (5-year project began in 1990)

(2) *Ceramic Methanol Engine*—(Leader: Norimasa Iida). The objective of the research is to realize an environmentally clean, (minimal NOx emission) compact and highly efficient engine by substituting heat-resistant ceramics for conventional combustion chamber components combined with the use of methanol fuel and an in-cylinder direct cooling system. In addition to reducing environmental pollutants in exhaust emissions, emphasis is given to alleviating dependence on fossil fuels in the future. (3-year project began in 1990)

(3) *High-Functional Membrane and Devices for Molecular Recognition*—(Leader: Toshihiro Akaiki). The project focuses on replicating the functions of living organisms, e.g., humans, by promoting advanced technological development and designing special materials for molecular devices capable of imitating biological functions. Anticipated applications are the realization of synthetic materials capable of mimicking the complex functions of living organs for implementation in artificial organs, cells, and biosensors. (5-year project began in 1990)

(4) *High Purity Compound Semiconductor Crystal—Leader*: Yasuo Okuno). The purpose of this project is to establish the procedure to grow ZnSe crystals suitable for practical use in blue light emitting diodes. Applications are to thin television and other display devices, and new optoelectronic devices such as pure-blue LED and semiconductor blue lasers. (3-year project began in 1991)

(5) *Human Protein*—(Leader: Seishi Kato). This project aims at developing new methods for approaching human proteins from genes by using recombinant DNA technology instead of conventional protein approaches. Applications include development of human proteins that can be used as medicine for diagnosis and therapy, and as new materials for bio-industry. (3-year project began in 1991)

(6) *Supermagnetic Materials*—(Leader: Hirohisa Uchida). The aim of this project is to create new magnets with magnetic energy densities far higher than those currently commercially employed and giant-magnetostrictive materials and their thin film devices that exhibit high-elastic strains when exposed to magnetic fields. The development of new magnets could promote the miniaturization of office automation equipment and electric motors. Giant-magnetostrictive materials have applications in powerful sonar devices, uses in microdynamics and surface acoustic wave devices, etc. (3-year project began in 1991)

(7) *Ultimate Mechatronics*— Leader: Toshiro Higuchi). This project proposes to develop revolutionary machines to operate under such extreme environments as vacuum and cryogenics, and to pursue the limits of performance of mechatronics technology and their applications in industry. Research is being conducted to develop muscle-like electrostatic actuators, micro robots, and non contact wafer transporting systems. (5-year project began in 1992)

(8) *Hu-Mouse: Model Animals for Research in Human Diseases*—(Leader: Yoshito Ueyama). This research is focused on developing model animals that accept human cells of tissues, and the methods to study human diseases and to develop therapeutic agents using these model animals. Research will attempt to develop such model animals, and methods for transplantation of human cells and tissue to these animals. (5-year project began in 1992)

Higuchi is one of the world's leading researchers in the design and application of Magnetic Bearing devices and actuators. Since Magnetic Bearings are free of mechanical friction, these have a variety of exciting applications, especially in use in robots where there are no contact bearings to generate dust, and hence of tremendous interest in clean-room environments. (Higuchi has coined the term Magnetic Servo Levitation for some of these applications.) This particular project, however, is broader, and looks at special environments more generally, such as ultrahigh vacuum, ultracleanliness, cryogenics, high-temperature, and high-pressure. Higuchi feels that such environments will become increasingly important in the development of ultra-precise instruments, new materials, biochemical technology, space, and other fields. The goal is to eliminate the requirement of human operation in such environments, since human operation is impossible, inconvenient, and unsafe. In these circumstances, conventional mechatronics (the fusing of mechanical and electronic engineering) is typically not applicable either.

The scale and style of Higuchi's project (as well as the other KAST projects) are approximately the

same as ERATO (Exploratory Research for Advanced Technology) projects that are sponsored by STA (Science and Technology Agency); however, KAST is a Prefectural, not a federal entity. KAST prefers project leaders who reside in Kanagawa and are under 45 years old at the start of the project. Like ERATO, projects are essentially driven top-down by their leader, rather than by proposals of individual researchers. Each project is funded at about Japanese¥1B for five years, about US$1.8M per year, and typically supporting about 10 researchers per project. An international advisory board of very senior scientists provide suggestions and management guidance, although they are not directly involved in the research details. In the case of the Higuchi project, in 1992 the budget paid for the services of 3 full time researchers (3 additional researchers will be hired in 1993). In addition, industrial organizations (preferably, but not limited to those in Kanagawa) can also join the project by paying a small fee to KAST. This allows them to send their own researchers to assist Higuchi. In 1992, seven such researchers were so employed, and in 1993 at least 12 company researchers will participate.

The generous budget allows Higuchi to purchase lab supplies. I am not an expert in this subject, but there was no doubt that his KSP labs were large, new, and full of expensive electronic and electromechanical equipment.

Professor Higuchi has divided the research into two major threads, each with several subparts.

Ultimate Environmental Mechatronics

(1) Ultrahigh Vacuum Mechatronics Production processes, such as for semiconductors, seem destined to continue to take advantage of ultrahigh vacuum, an environment with few impurities. In an ultrahigh vacuum, not only is the use of vapor releasing lubricants prohibited, but there are also other restrictive conditions preventing the use of mechanical elements common to standard environments. Therefore, robots incorporating magnetic levitation technology that can function in a vacuum are to be developed and later be combined with a vacuum chamber and wafer feeder in a prototype semiconductor system. The aim of this development is to enable semiconductor production without the need for a clean room.

(2) Cryogenic Mechatronics Cryogenic environments that exhibit minimal thermal noise are of tremendous interest. To use such environments, electric motors and positioning mechanisms that can operate in and preserve cryogenic conditions must be developed for experimental and analytical equipment. For this purpose, Higuchi plans to develop actuators equipped with a new mechanism that integrates piezo-electric devices and superconductive materials.

Ultimate Function Mechatronics

(1) *Ultraprecision Mechatronics*. To work at atomic or molecular levels on the surfaces of materials, specimens and probes must be positions with Angstrom accuracy. As an example, proposed positioning mechanisms will have scale graduations as fine as the atomic separations in a reference crystal lattice resolved by a Scanning Tunneling Microscope.

(2) *Micro-Mechatronics*. This focuses on the miniaturization of automated machinery, typically robots. Higuchi feels that the most important key to this development is the micro-actuator. His targets are the development of an electrostatically driven actuator device and its production method. One variation of this electrostatic actuator could be used as a direct paper feeder that would reduce the size of office automation equipment such as printers and faxes.

(3) *Bio-Mechatronics*. Higuchi is planning to develop technology for the 3-D manipulation and observation of in-vivo microorganisms by employing static electricity and micromanipulators. One such device is a high-speed DNA genetic information reading system that will use a Scanning Tunneling Microscope or an Atomic Force Microscope to resolve the structures of DNA molecules so finely that each atom will be identified.

Higuchi showed me a variety of experiments. Many of these take advantage of his work in electrostatic actuators, which will be expanded during this KAST project. A very recent paper on this work was presented last month at the IEEE Workshop on Micro Electro Mechanical Systems (7-10 Feb 1993, Fort Lauderdale, Florida) and published in their Proceedings (IEEE Catalog Number 93CH3265-6), "High-Power and High-Efficiency Electrostatic Actuator" (Nino, Egawa, & Higuchi). He demonstrated an electrostatic stacked film actuator with significant power to weight as well as force to weight ratios (such a device was able to lift approximately 70 times its weight). He showed me examples of

such devices moving sheets of glass, paper, and (through an artificial arm) lifting. These devices also displayed the ability for rapid direction changes and significant linear motion capability. Frankly, it doesn't take much imagination to envision such devices used in printers or other paper moving products. Higuchi also feels that they can be made suitable for use in wafer processing in vacuum, (electrostatic levitation of wafers). This is now often done by air movement in standard atmosphere. He also showed me a project that uses standard computer graphics to generate computerized 3-D images by 2-D sections, in this case, frozen slices of a tick. The relevant aspect here, was to use precise positioning in order to generate slices at 0.1micron pitch. Other work involves using an STM for measurement and ultraprecise positioning. Finally I saw some examples of an electromagnetically supporting system to measure and identify the levitating properties of superconducting material. Higuchi feels that this apparatus may be a standard of levitation properties of such materials with magnets.

The Office of Naval Research will support Prof. Paul Ro [Email: RO@PESUN.PEC.NCSU.EDU], of the Precision Engineering Center at North Carolina State University, to spend a month working with Prof. Higuchi early this summer. Professor Ro plans to issue a report on this collaboration and other aspects of this project.

Two upcoming conferences are of potential interest.

Seventh International Precision Engineering Seminar
17-23 May 1993, Kobe Japan
Contact:
IPES-7 Headquarters
Dept of Precision Engineering
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7th IEEE International Workshop on Micro Electro Mechanical Systems
25-28 Jan 1994, Oiso, Kanagawa, Japan
Contact:
IEEE MEMS-94 Workshop
c/o MESAGO Japan Corp
Palais Eternel 1004
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(Prof. Higuchi is also a General Cochair of this Workshop)

TAIWAN'S NATIONAL CENTER FOR HIGH PERFORMANCE COMPUTING 28 APRIL 1993

The opening of Taiwan's National Center for High-Performance Computing (NCHC), 19-22 April 1993, HsinChu Taiwan, is described. Also, brief comments on a visit to Taiwan's Data Communications Institute are included.

David K. Kahaner

Several times I have written about the establishment of a new national supercomputing center in Taiwan, even before it was built. (For example, refer to "taiwan12.91" 16 Jan 1992, and "taiwan3.92", 24 April 1992.)

Recently, I traveled to the city of HsinChu, about one hour southwest of Taipei to participate in the formal opening of this center and the associated conference, "International High-Performance Computer Conference" (IHCC'93). Although there are many supercomputers in Asia, to the best of my knowledge, Taiwan's National Center for High-Performance Computing (NCHC) is the first truly national center in this part of the world, and for this the Taiwanese science community should be congratulated.

The National Center for High-Performance Computing in Taiwan is a two year old effort by the government to promote and develop high-performance computing in Taiwan. It is a division under the National Science Council (NSC) that is similar to the National Science Foundation in the United States, and in fact Dr. N.H. Kuo, the Chairman of the NSC, gave the opening address. He emphasized the role of the center as a tool for research, as a balanced resource among academia, government, and industry. He also expressed his expectations that the center will permit Taiwanese scientists to become more active members of the international community.

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In many ways, NCHC is similar to a National Science Foundation center in the United States, and an important part of the opening ceremony was the signing (by Greg Galvin of Cornell University) of an agreement with their sister organization, the Cornell Theory Center. The main effects of this agreement are related to information and people sharing. In fact, several Taiwanese scientists are slated to spend some months at Cornell in the near future.

Galvin also gave an interesting talk about new ideas of cooperation between universities and industries. He commented that in the past they have been either bilateral (a faculty member and corporate person with similar interests agree to collaborate) or affiliates programs in which companies pay US$10-50,000 to receive publications, have some faculty access, and invitations to annual review meetings. In recent years, however, affiliates have lost some of their appeal, as interaction between the company and academic organizations has been shown to be limited, and in any case the information flow is all one way, out of the university. More recently, a new model of cooperation, a partnership, has become prevalent, and Galvin felt that it will become the dominant form of university-industry collaboration in the 1990s. Typically, partnerships involve a joint definition of work to be performed, usually over several years, and often with personnel exchanges in both directions. He also pointed out

the three points of scientific discovery, technical leadership, and public service that need to be emphasized, the role of university-industry collaboration in each of these, and finally, some examples of active collaboration in place at Cornell today.

In addition to Cornell, NCHC signed an agreement with IBM. This will open IBM's research labs and will place 24 Taiwanese scientists at a variety of three-month assignments in these labs during the next two years.

NSC has funded NCHC with about US$100M over five years.

NCHC's new building is completed. It has 150K square feet of office space on four floors and has plenty of space for expansion. Construction appears to be impressive, with marble flooring almost everywhere, and very nicely placed offices. We were told that construction costs were on the order of US$13M, a figure that seems quite low considering the size and quality of the building. The entire building is cabled with FDDI and is T1 linked to the Universities as part of TANET . With this connectivity, it is hoped that most academic researchers in Taiwan will be able to reach the NCHC equipment from their own office.

The NCHC is located in the HsinChu Science-Based Industrial Park. This Industrial Park is also an effort of the Taiwanese government to promote high technology in Taiwan. The industrial park was founded 13 years ago on 1500 acres, and now it supports about 25,000 workers in 140 companies. Adjacent to NCHC is an almost commissioned synchrotron radiation source, the only one in Taiwan. HsinChu is located about 75 Km south of Taipei along the main North to South highway.

Currently, 65 employees are working at the NCHC. Plans are to hire an additional 10 people within a year. The breakdown of the total number of employees is:

Administration	14
Research and Promotion	28
Computer Services	10
Consultants	11

The research and promotion staff is charged with promoting and educating Taiwan about the benefits of High-Performance Computing. They will also be involved in their own research. All of them have advanced degrees, about half of them have Ph.D.s from the United States.

The consultants are distributed throughout Taiwan with one at each of the 11 major Universities and Academica Sinica. They help with access to NCHC, stabilizing TANET (the Taiwan Academic Network), optimizing programs, and training users. In fact, several training courses have already been given, and there is a plan to allow public school students to be exposed to the center equipment during this summer.

The director of the Center is Dr. San-Cheng Chang, who is on leave from the Civil Engineering Department at National Taiwan University (in Taipei). His deputy director is Mr. Kuo-Wei Wu, who for a long time was an employee of Cray Research. Dr. Jin Su is in charge of the division of Research and Promotion. Mr. Gen-Shen Lin is in charge of the Computer Services.

Currently, NCHC has:

IBM ES9000 (5 Processors)
Convex 3840
4 HP 735s
4 IBM RS6000 model 580
4 IBM RS6000 model 560
4 SGI Crimsons,
4 SGI 4D/310, and
1 SGI 4D/35
Approximately 150 Sun SPARCstation ELC (b/w) workstations.

Last year I reported on the choice of IBM as a major vendor. This might be a little surprising given the experience of several key NCHC staff members on Cray systems, but it is mostly a reflection of the fact that there is already a significant IBM and Convex presence in Taiwan, as well as very active sales and marketing operations for both of these companies. However, an open procurement was done with at least one Japanese vendor (NEC) competing.

The original NCHC plan that I described in an earlier report, anticipated an upgrade to an SS1 machine from Steve Chen's SSI in 1995. As most readers know, this company had significant financial support from IBM over several years (the partnership also included DuPont, Boeing, Electricite de France, and Ford). IBM's commitment to SSI ended several months ago, and IBM chose not to continue

their funding. Chen has attempted to obtain funding from other sources; however, this has been unsuccessful, except for an offer of US$100M over one year from a joint venture that included at least one organization that was an extension of the Government of the People's Republic of China. Ultimately, this offer was withdrawn and, to the best of my knowledge, Chen is now considering other product possibilities, such as producing a high performance workstation. In any case, the possibility of a large supercomputer by 1995 from this source seems remote, and NCHC is already thinking about their upgrading opportunities. They will be looking at the possibility of parallel computer and a distributed workstation environment.

During my week at NCHC, several of the ELC sparkstations were available for use for electronic mail via TELNET. Access to Tokyo was quite slow although functional, but it was somewhat better to the United States. However, one problem was a very poor keyboard response on the ELCs, which exhibited a tremendous amount of key bounce. I had so much trouble that eventually I abandoned any attempt to edit files. Most of the other visitors had similar difficulties on each of the available machines, and this was also confirmed by Dr. Chang who felt that there was a design problem. (The ELCs were offered to NCHC at extremely favorable terms, although I am told that there is now some effort on the part of at least one other vendor to get NCHC to trade them in.)

International High-Performance Computer Conference '93

Associated with NCHC's opening was an exhibit and conference, IHCC'93. A major goal of this conference was to publicize the NCHC to all Taiwan researchers in government, academia, and industry, and to increase communication between researchers and NCHC. In this regard, it seemed that the organizers were quite successful. The conference had about 375 attendees for the guest speaker's tutorials. Also there were 21 vendor presentations and 21 vendor exhibits. These were open to the public. There were 450 (including high school students) who attended these vendor activities.

Sixteen guest speakers had been invited as experts in their own fields. They were asked each to give presentations of a survey of their field and then a more detailed look at their own current interests. The speakers and topics were:

Jack Dongarra
Univv. of TN & ORNL
Lapack and XNETLIB

Michele Parrinello
IBM
Ab-initio Molecular Dynamics

Hal Alles
SGI
ICs and ASICs

David Kincaid
Univ. Texas
Iterative Methods

Ted Belytschko
Northwestern
Nonlinear Finite Elements

Jan Andzelm
Biosym
Density Functional Methods

Iain Duff
Harwell&Cerfacs
Sparse Solvers

John Larson
CSRD
Performance Modeling and Benchmarking

Robert Manchek
Univ. Tenn.
PVM

Arie Kaufman
N.Y.U.
Volume Visualization

William Goddard
MSI
Material Science

Tony Chan
Univ. Hong Kong
Parallel PDE Algorithms

Michael Frisch
Gaussian
Electronic Structure Theory

David Keyes
Yale
Parallel CFD

Hans J. Hermann
KFA, Germany
Molecular Dynamics

Joseph Fisher
Hewlett Packard
Compiler Technology

This conference provided the local researchers a chance to listen to and talk with known experts in a wide range of fields. There were no Taiwanese speakers.

Two lively panel sessions were held at night, moderated by Mike Ess of NCHC. Their topics were:

- Benchmarking: Art or Science?
- What will be the Computing Center of the Future?

The vendor presentations included the following (I didn't actually go to all of these, so I cannot attest to the actual participation of all the people named below).

SGI
Practical Parallel Processing

BIOSYM
Jan Andzelm
Quantum Chenistry, software demo

Tripos
Scott A.Gothe
Sybyl 6.0

Convex
Steve Wallach
& David Keck
Metacomputing

HP
Joseph Fisher
PA-RISC

nCUBE
Bob Enk
Forge 90

MSC/NASTRAN
Dr. Hsieh
NASTRAN Applications

DYNATECH
David Byrne
CFD software

DEC
Jeevan Kumaran
Workstation Farms

IBM
Mr. Yu & Mr.Ma
IBM RISC & ES9000

TATUNG
Mr. Fan & Mr. Cheng
Phoenics & FEA

HO-MEN
Mr. Yang & Mr. Cheng
Anvil 5000 CAD/CAM

Mentor Graphics
Mr. Wang
IC Design Methodology

Abaqus
Mr. Ling
ABAQUS Applications

MSI
Mario Blanco
Polymer and Materials Science

Neither the tutorial speakers nor the vendor sessions offered any Japanese participation. Mr. Wu commented to me that Taiwanese people have some difficulty understanding the English spoken by the Japanese. (Also, I was told that Cray Research attempted to participate in the vendor sessions, but only at a very late date, therefore, it was not possible to accommodate them.)

The format of the conference was clearly modelled after supercomputing conferences in the West, with technical sessions, exhibits, and vendor presentations.

Overall, I felt that just about everything concerning NCHC was smart, for Taiwan. There is a clear view that the center will be a focus for applications of high-performance computing, and I sensed

no serious interest in its being a testbed for new architectures or related activities that did not have research into applications as a theme. This makes sense, because of the needs in the country. Similarly, the conference was a direct effort to bring Western experts to Taiwan to inform Taiwanese scientists about state-of-the-art research in a broad collection of technical areas. As part of the opening ceremony, Professor J. Dongarra (University-Tennessee) announced that NCHC would soon become a NETLIB distribution center. This means, in effect, that a vast collection of public domain software will soon be easily available to Taiwanese scientists via electronic distribution. This is another smart example of providing technology input to a scientific community anxious for the information.

It will be most interesting to return to NCHC next year and to hear about the progress made by Taiwanese scientists in making use of high-performance computing for their own research activities. The address of the NCHC is:

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DATA COMMUNICATIONS INSTITUTE (DCI)

[To be added shortly...]

For readers' information, the following statistics about Taiwan may be of some interest.

Population:	21M
Pop growth:	1.2%
GNP/per capita:	US$10,215
GDP growth:	6.1%
Exports (12 mos):	US$82.5B
Current account surplus:	US$7.9B
Foreign debt:	0
Inflation CPI	3.2%
People/telephone	2.4

SELF REPAIRING COPIER 15 MAY 1993

This article gives information about ongoing research at the University of Tokyo on machines that maintain themselves, with specific application to a more reliable copier.

David K. Kahaner

In an earlier report, "copier.93", of 10 April 1993, I transmitted a short description of a copying machine with features of self maintenance. Because of the many requests by readers about this , I have taken a more detailed look at the subject.

I visited the laboratory of:

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Mainly, three researchers have been working on this project, Prof. Tetsuo Tomiyama, Prof. Hiroyuki Yoshikawa, and Dr. Yasushi Umeda. Professor Yoshikawa has recently taken over the position of President of the University of Tokyo, therefore he is no longer actively engaged in this project. Dr. Umeda, a research associate hosted my visit.

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Although my earlier report focused on a copier, and in fact this is the main platform for the lab's research, their basic interests are in knowledge acquisition, fault diagnosis, repair planning, and functional redundancy when applied in the context of self maintenance. Thus, since their ideas are generalizable, it might be possible to implement their approach in a variety of other applications.

Unquestionably machines wear out, break, or go out of adjustment. Depending on the environment, this can be irrelevant or catastrophic. Dr. Umeda and his colleagues are interested in a "self maintenance machine" (SMM), a machine plus a computer system that performs its designed functions for some specific period, even if some faults occur, by controlling its parameters and structures, by itself. Specifically, they expect that a SMM should have the following capabilities in addition to its required principal functions.

- Monitoring
- Fault judging,
- Diagnosing,
- Repair planning,
- Repair executing.

Obviously it is impossible to develop a perfect SMM; however, this group has been studying ways to make machines work (perhaps not perfectly or for a long time) once a fault has been detected. Their research has evolved in two levels.

First, a methodology that relates to adjusting values of machine parameters (based on sensor output) through some control (actuation) mechanism. In the case of a commercial copier, which is referred to as the "object machine," four sensors were installed or used if already in place, as well as three controllers, such as main halogen lamp, main charger, toner density, photometer, surface electrometer, densitometer, transcharge sensor. In their work, the researchers connect a Mita copier to a

board on a MS-Dos PC, which is in turn connected through an RS232 line to a Mac IIx or a Sun Sparc ELC workstation. The PC has a better interface to the copier, but a model based planning system, qualitative simulator, are running on the Mac or Sun, where the software development is done.

This type of automatic repair controls the actuators so that by adjusting the parameters, the SMM tries to recover part of its requested functions. Some part of these functions might be lost or degraded, but the important functions need to be maintained, e.g., functional trade-offs. For example, in the copier, when the halogen lamp brightness decreases the transfer charger controller can be used to adjust brightness of the image. In this sense, the state of the machine is unchanged, e.g., everything is functioning albeit at different setting. The group's view is that the design parameter space of the machine can be enlarged through degradation to a larger, but still acceptable space.

A second type of repair that the researchers call "functional redundancy" to distinguish it from "part redundancy." The latter is the usual repair mechanism, e.g., including additional redundant parts. Functional redundancy uses potential functions of parts in a different way from the original design. One example is the use of the starting motor of an automobile to generate driving force in an emergency situation. In the context of a copier, a function might be to charge the drum, normally done by the main charger. But copiers also have a second charger, the transfer charger whose main function is to transfer toner from the drum to the output paper. If the main charger fails, the transfer charger can be engaged to charge the drum in addition to its primary function to transfer toner.

For this to work, it is necessary not only to have the sensor data, but perhaps more importantly to have a model of what the machine is supposed to do, and how parameter changes affect machine functions. So a key ingredient is the development of a system model. I don't see any way other than having this produced by or with the assistance of experts. But this is also consistent with the current trend to design and "build" the total system on a computer before any actual manufacture is done.

This involves conceptual design, basic design, and control sequence design. (The latter is the set of control codes used in embedded cpus.) Functional redundancy is designed in during the first step, or conceptual design. To do this the research team has developed a suite of tools, in particular a Function-Behavior-State (FBS) Modeler based on the notion of an FBS diagram. The modeler represents design objects based on the diagram. It allows the representation of functions in an object oriented manner. This work extends knowledge representation work of Forbus in the area of qualitative process theory, implemented by qualitative reasoning (cost, or other quantitative issues are not modelled.) A key part of representation is the decomposition of functions, allowing the designer to build up a functional hierarchy. Ultimately behavior simulation can be performed with a reasoning system providing a variety of information.

The software tools can be used in traditional computer aided design environments, but the group has also developed another support system, a Functional Redundancy (FR) Designer for their new application. This works on top of the FBS Modeler. The user (designer) selects a target function and the FR Designer generates candidates for functional redundancy for the target function by searching. However, the user needs to select the most appropriate based on cost, reliability, etc. There is a nice graphical interface for the output, but I am not sure how effective it would be when used on very large, complicated systems. The FR Designer also provides some information on robustness and redundancy in a qualitative sense.

There is also an interesting reasoning system based on work by Crow & Rushby on model based reasoning. This can be used to construct fault models, and fault diagnosis by comparing the fault models with actual symptoms. Since the system also simulates behavior of the object machine when repair methods are executed, it can estimate side-effects of the reasoned repair methods and can add repair methods against these side-effects. For functional redundancy repair, the reasoning system assures that malfunctioning parts in the object model should not be included in the alternative model of the FR repair.

At least two commercial Mita copiers have been instrumented to test these techniques (parameter adjustment and functional redundancy) in the lab. Small changes are required to the hardware as mentioned earlier, as well as changes to the embedded computer software. The latter turns out to be somewhat of a problem if large numbers of functional redundancies are admitted. (In fact, a Mita employee working in the lab admitted that keeping the cpu cost controlled was a concern. Nevertheless, Mita is planning to produce a copier for sale with

some of these SMM functions included, within a year.) The research group have also been working on software that will automatically generate these control sequences directly from the design information, via a Control Sequence Program (CSP) Generator. Work on this is to be presented Aug 1993 at IJCAI'93 in France.

Some work incorporating fuzzy theory has also been done. Fuzzy qualitative physics has been tried to simulate deterioration of a machine and also to order fault candidates by using sensor data as well as simulated data. This has not gone too far though; Umeda feels that the main problem is the determination of the fuzzy membership functions. An object model editor has also been developed.

I like the direction that this research is taking. Generally, there is a rapid infusion of software methodologies into hardware design, or equivalently the transformation of hardware design into the software domain. This research meshes nicely with the trends in computer modeling of manufacturing and computer design of manufacturable systems, and represents an extension of the tools now available to the designer. I cannot yet tell if the useful functional redundancy would be obvious to the experienced designer or eye opening, deduced by the reasoning. More practical application while Umeda and others in the research team are equally interested in the aspects of knowledge representation and reasoning. For the future it will be important to see how useful are the tools that have been developed, the FR Designer, etc., and whether they can be used on new problems, or if too much of their design anticipates the specific copier application.

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NEW ARCHITECTURE FOR SOFTWARE STRUCTURE PROJECT (AIST)

Overview of AIST's Basic Technology for Future Industries R&D projects & additional details of one, New Architecture for Software Structures.

David K. Kahaner

INTRODUCTION

AIST (Agency of Industrial Science and Technology, which is part of MITI) sponsors a variety of major R&D programs such as the following.

- National Research and Development Program (Large-scale project)
- Research and Development Program on Basic Technologies for Future Industries (JISEDAI program)
- National Research and Development Programs for Medical and Welfare Apparatus
- Research and Development on New Energy Technology (Sunshine project)
- Research and Development on Energy Conservation Technology (Moonlight project)
- Research and Development on Technologies Related to Global Environment
- The Human Frontier Science Program.

There are also programs in industrial technology, international cooperative R&D, technology promotion, standardization, and technology information. From the details of these programs, readers may have a tough time deciding why one specific research project is in a particular category but not in another. AIST has come to a similar conclusion. I am told that beginning next fiscal year, 1 April 1993, these large programs will be reorganized. For example, the first three above will merge into a new title, "Leading Research Schemes", and that the energy related projects will fall under the "New Sunshine Project". Ongoing projects will be continued, but new project proposals will undergo a more public feasibility phase before a final decision as to their acceptance.

In the meanwhile, I attach an overview of the Basic Technology for Future Industries (abbreviated as the JISEDAI Program), because it has one very interesting software component. But readers should be aware that JISEDAI will probably disappear within a few months.

This report summarizes the AIST R&D program on Basic Technologies for Future Industries (JISEDAI) and provides some additional details on one specific project, New Architecture for Software Structures.

GENERAL: JISEDAI PROGRAM

Research and Development Program on Basic Technologies for Future Industries (JISEDAI Program) 1992.

Introduction

In 1981, MITI started the Research and Development Program on Basic Technologies for Future Industries (JISEDAI Program) as part of the national industrial policy to promote the research and development of innovative basic technologies under the control of the Agency of Industrial Science and Technology (AIST).

Here, the program and the specific R&D operating projects are described.

Objective

Japan has previously pursued technological development mainly in the field of applications, but now is more important to promote the research and development of basic technologies applicable to a wide range of industries and to continue the essential technological evolution.

As the Japanese economy has continued growing, Japan has been asked to contribute to the world economy by developing basic technologies.

The JISEDAI Program started in 1981 with the development of innovative basic technologies necessary to establish such future industries as aerospace, information processing and bioindustry, and also to upgrade a broad range of existing industries.

Target Fields

The selection of projects for the program is based on the following criteria:

- Highly innovative basic technology with far-reaching effects.
- Technology that generally requires 10 years or more of research and investment risk.
- Basic technology with potential applications in the future.

[DKK comment:
AIST's "Large-scale Project" lists as its criteria.

1. Pioneers large-scale industrial technology essential and urgent for the national economy.
2. Requires considerable funds, long lead time and risks.
3. R&D in the private sector is difficult.
4. The R&D project should contribute to international society by addressing international problems.
5. The R&D project should enrich life.
6. The R&D projects should establish a sound industrial society.

The following are the current projects and their FY92 budgets.

- Manganese nodule mining system, Japanese¥0.9B
- Advanced material processing and machining system, Japanese¥2.6B
- Fine chemicals from marine organisms, Japanese¥1.4B
- Super/hyper sonic transport propulsion system, Japanese¥3.8B
- Underground space development technology, Japanese¥1.4B
- Advanced chemical processing technology, Japanese¥1.7B
- Human sensory measurement application technology, Japanese¥2.0B
- Micromachine technology, Japanese¥2.0B
- Ultimate manipulation of atoms and molecules (new), Japanese¥0.03B.

end DKK comment]

In FY 1992, 11 R&D projects in the five fields,
- superconductivity,
- new materials,
- biotechnology,
- new electronic devices, and
- software,

have continued.

(1) Superconductivity (1 project)

Superconducting Materials and Devices—Superconducting materials can be used in fields such as electricity and electronics based on new high-temperature superconducting materials by establishing basic process technology for applications and by developing high-performance superconducting materials.

With the development of high-temperature superconducting materials, the many difficulties experienced in cooling conventional superconducting materials that have hampered the application of superconductors to energy systems such as superconducting generators, transportation systems such as magnetic levitation railways (linear motor cars), and electronics systems such as superconducting computers, are expected to be overcome, and the materials developed will be applied to many fields.

By establishing basic technologies essential to electronic devices that use high-temperature superconducting materials, new practical devices with advanced functions can be developed.

Superconducting devices are expected to realize high-speed switching circuits and to decrease power consumption. Their physical properties may open up a new application field of electronics.

In the future, a new compact computer will be developed by using superconducting devices that will achieve ultrahigh-speed processing with high-density.

(2) New Materials (5 projects)

High-performance Ceramics—High-performance ceramics as a structural material applicable at very high temperature with improved reliability, high-

corrosion resistivity, dimensional accuracy and hardness will be developed by solving the brittleness and difficulties in machining and bonding.

Successful R&D will contribute to many future industries such as nuclear, new energy and aerospace industries, and at the same time achieve greater energy saving through the improvement of thermal efficiency of heat engines.

High-performance Materials for Severe Environments—Intermetallic compounds, their composite materials, and carbon fiber/carbon-based-matrix composite materials will be developed as advanced high-performance materials durable under high-temperature conditions.

The performance of the equipment in aerospace, nuclear power, new and alternative energies will dramatically be improved. Furthermore, considerable energy conservation will be achieved through improved thermal efficiency engines using these newly developed materials.

Photo-reactive Materials—Photo-reactive materials are being developed in which light controls the molecular structures and aggregation states, and can be used for superhigh-density recording equipment.

The new materials will promote the development of technologies such as a superhigh-density system for supercomputers, and ultrasmall disks for business and home use. They are also expected to contribute to high-resolution and 3-D displays.

Nonlinear Photonics Materials—Advanced photonics materials will be developed with nonlinear optical susceptibilities to be used for photo-logical switches.

The new materials will promote the development of an optical computer capable of large-capacity and high-speed information processing. Use in technologies for optical communication is also expected.

Silicon-based Polymers—Efforts will be made to develop silicon-based polymers with better electronic and optical functions, thermal stability, and mechanical characteristics than the existing carbonbased polymers.

These materials will be more adaptable than conventional materials, and are expected to be used in many industries including aerospace, electronics, household products, and construction.

Also, these materials will cause less environmental pollution than carbon-based polymeric materials, because of their lower C02 emission when burnt.

(3) Biotechnology (2 projects)

Molecular Assemblies for a Functional Protein System—Basic technologies for artificial reconstitution of molecular assemblies to promote specific multistage reactions will be developed. Highly controlled chemical reaction processes with high selectivity may be realized.

Production and Utilization Technology of Complex Carbohydrates—Carbohydrates, one of the four basic substances that compose organisms, (nucleic acids, proteins, lipids, and carbohydrates) have unique and important functions in organisms, and industrial applications are possible. For example, glycosylation of enzyme improves functions such as acceleration of reaction speed and recognition of cells and molecules with high specificity. Also, carbohydrates are useful for separation and purification technology.

The technologies for production and use of complex carbohydrates with carbohydrate chains designed to add functions such as thermal stability, durability, and specific recognition will be developed.

(4) New Electron Devices (2 projects)

Bioelectronic Devices—Bioelectronic devices will be developed by elucidating the principal algorithm of information processing and learning functions in the neural system and by establishing technology to maneuver molecular assemblies that realize unique functions such as plasticity, molecular recognition, and self-organization.

These information processing technologies are expected to develop a new teaming or pattern recognizing system and to realize a biocomputer in the future.

Quantum Functional Devices—Basic technologies for developing new devices with ultrahigh-speed and multifunctions are to be established by controlling quantum effects such as the tunneling or interference of electron waves appearing in ultrafine semiconductor structures (less than 0.1 μm).

New devices will be realized by finding new operational principles, by controlling the quantum functions, by fabricating quantum-sized structures, and by constructing new integrated circuits.

The quantum functional devices will be super-high-speed and dense-integrated devices with low-power consumption. They will have applications in such areas as supercomputers, high-speed image processors, high-performance oral translators, and huge-system simulators.

(5) Software (1 project)

New Models for Software Architecture—New models for software architecture will be developed, which will flexibly and automatically adapt to changing circumstances through the cooperative problem-solving functions of software modules.

These new models for software architecture are expected to lay the foundation for software technology to make system development/maintenance easier, satisfy various needs, and cope with unexpected situations.

R&D Method and Implementation

In principle, parallel development systems are to be adopted so that each participating research institution can use its own research method. Also, to streamline the R&D system, project progress and results are to be evaluated based on "R&D Basic Plan", which should cover a period of about 10 years. Targets are to be established for each project.

This program is to be carried out with the cooperation of industry, academia, and government (national laboratories). Some projects are to be contracted to private corporations and the like through NEDO (New Energy and Industrial Technology Development Organization), while other projects are assigned to national laboratories and universities on a merit basis.

Specifically, the program participants work under the following bodies.

- The Next-Generation Industrial Technology Planning Office, through which MITI promotes the program by coordinating it with industrial policies.
- The Industrial Technology Council for discussing the R&D Basic Plan and the like, which is the framework of the R&D activities over a decade.
- The Promotion Committee for coordinating and discussing, at research implementation level, the R&D projects implemented by national research institutes and private corporations.
- R&D Coordinators who provide long-term guidance on the R&D projects, thereby directing the projects.
- The Evaluation Committee where various experts from project participants evaluate R&D results.

Budget

Budgets for FY 1992 and the preceding years are shown below for each of the five fields of R&D.

Field	Budget for FY: (in B of Yen)												
		81	82	83	84	85	86	87	88	89	90	91	92
Superconductivity									1.1	1.9	2.3	2.8	2.9
New Materials		1.4	2.6	3.2	3.3	3.6	3.6	3.6	3.1	2.8	3.8	3.9	3.6
Biotechnology		0.7	1.0	1.2	1.2	1.3	1.2	1.1	0.9	0.8	0.5	0.6	0.8
New Electron Devices		0.7	1.1	1.5	1.5	1.6	1.5	1.4	1.2	1.3	0.8	0.3	0.8
Software											0.1	0.3	0.3
Total		2.7	4.8	5.9	6.0	6.4	6.5	6.0	6.4	6.8	7.5	7.9	8.8

Participating institutions:
Private corporations: 62 with 88 separate groups
National research institutes: 12 with 38 separate groups
Universities: 53

MITI expects by the end of FY '91 to have more than 600 patents and almost 10,000 research results to present to the public at an annual JISE-DAI Industrial Basic Technology Symposium.

SPECIFIC: NEW ARCHITECTURE FOR SOFTWARE STRUCTURES PROJECT

The project started in FY-1990 with a term of eight years. "Sufficient funds for research and development will be provided by the government." (1990, 1991, and 1992 FY budgets were Japanese¥53M, 270M, and 283M respectively.)

New models for software architecture are to be developed that will be flexible and automatically adapt to changing circumstances through cooperative problem-solving functions of software modules.

The goal of the project is to develop a new software methodology for building large complicated systems out of simple units. The emphasis is on the architecture that is used to combine the units, rather than on the intelligence of individual units. The cooperative problem solving of units is the essential concept for the project. The word "cooperation" is used here only to refer generally to mechanisms by which large systems combine smaller units in contrast to the wider connotations of the word.

By providing such methodology, the high-work load of software engineers in the development and maintenance of high-level software systems is expected to be reduced. As a consequence, both the software production process and the resultant software will be adaptable to the diverse needs and changes in social demand.

The project will use several different approaches.

1. *Top-down approach*. Analysis and modeling of cooperational tasks. This is further divided into two categories:
   - cooperation among software agents
   - cooperation between software and human agents
2. *Bottom-up approach*. Development of basic mechanisms and theory in the following fields:
   - situated reasoning,
   - self-reorganization of knowledge structures to adapt to environmental change,
   - computational model of cooperation,
   - semantic adaptation of inputs and outputs between agents.

Schedule

The term of the project is divided into three phases:

Phase I (1990-1993) - Initial Phase

A basic model of cooperative architecture will be established by analyzing several examples that require cooperation and by identifying essential issues. The specific goal(s) of the project and scale will be established in this phase.

Phase II (1993-1996) - Main phase

The details of the architecture are determined and feasibility evaluated by building actual programs. Problems found in the evaluation will be fed back to alter the basic design. This model-evaluation cycle will be repeated.

Phase III (1996-1998) - Establishment of new ideas

The results of the preceding two phases will be integrated into a new computational methodology for software science.

The research itself will be carried out cooperatively and flexibly by several institutes including national laboratories, universities, and company laboratories. There will be both domestic and foreign sites. Domestic as well as international cooperation is essential in this project. All the results of the project will be published as papers for immediate international availability.

Management of the project is also carried out in an adaptive manner taking into account

- progress and products of each phase,
- supply of research and development funds, and
- overall direction of research in related fields.

NECESSITY OF RESEARCH AND DEVELOPMENT

Complexity of the System

In the high-level information oriented society of the future, highly advanced computer systems will be basic in the social life of people. Such computer systems will become larger in scale, more complicated, and more diverse in use.

The progress in software technology is slow compared to the rapidness of hardware development that has been supported by remarkable technological advancement in recent years. This will create a large gap between demand and supply of software, cause development and maintenance of the software system to become significantly difficult, and become an obstruction in the achievement of healthy, high--level information oriented society.

The present technique of software development requires the whole design of the software system to be fixed in the specification step. Therefore, when software systems become larger in scale, a larger number of engineers, longer development periods, and more costs will be required to develop and to maintain the software systems. In addition, it is even predicted that stiffening of the software systems will result in considerable problems for our whole society.

To prevent this, research on the basic architecture of software must propose an innovative model for software architecture that makes it possible for a software system to change itself flexibly according to changes in the structure of society.

Personal Use

Progress in office automation and popularization of personal computers enable people, who are not computer specialists, to use software systems on various occasions. Current software systems are designed only to satisfy the basic, common part of users requirements, not to satisfy all requirements of all users.

The new model of software architecture must therefore be able to cope with the diversity of individual requirements by providing software systems that learn through environments of use and adjust to types of use.

Unpredictability and Risk of Research and Development

At present, the designer of a software system must foresee, at the time of design, all tasks and sources of problems the system may encounter and preprogram into the system all responses to all possible situations. It is of course impossible to forecast all events generated by a complex system and to prepare all solutions beforehand. Therefore, the new software architecture must enable design of software that has flexibility to adapt to the change of social demand by changing itself and to make flexible responses even when totally alien situations arise.

It is extremely difficult for private enterprises without the help of government to advance such research and development to establish the new model of software, since the risk is large because of the large sums for research and the long term research period.

Moreover, in this project, since the research is important to the high-level information oriented society, and since the idea originated in Japan, it is important to conduct the overall research and development and to provide other countries with the results.

DETAILED PLAN OF RESEARCH

Analysis and modeling of cooperative tasks (top-down approach)

- *Cooperation among software agents*—Basic requirements of cooperation will be clarified by analyzing and modeling actual cooperational problem solving tasks that should be carried out by software modules.

- *Cooperation between software and humans*—Basic requirements of cooperation will be clarified by analyzing and modeling various types of man-machine systems.

Development of basic mechanisms and theory (bottom-up approach)

- *Situational reasoning*—The goal is to provide a context sensitive representation and to enable the reasoning procedure to manipulate this representation so that the reasoning process can
  - reason about the context, and
  - change itself and/or the context if necessary.

  To achieve this goal, the information used in the reasoning process will be obtained from the context and the representation of the problem.

- *Self reorganization of knowledge structures to adapt to environmental change*—To adapt to changes in environment dynamically, an agent

has to modify itself. The basic mechanism to reorganize knowledge representation through inputs from environment will be studied and developed.

- *Computational model of cooperation*—Mechanisms for an individual agent, with partial knowledge, to autonomously behave in a way optimal to the required problem solving in cooperation with other agents will be studied and developed.

- *Semantically adaptive software modules*—Communication between agents cannot be fixed beforehand. Therefore, a method is required for each agent to understand other agents output semantically and to adjust its own output accordingly. The key is the mathematical specification of behavior.

EFFECT OF RESEARCH AND DEVELOPMENT

This new model for software architecture is expected to be a key technology for software that enables programs

- to make system development easier,
- to make system maintenance easier,
- to satisfy various needs, and
- to handle unexpected situations.

High-Level Information Oriented Society

In a high-level information oriented society, computer systems are basic and central to social life. A large number of high-level, complex, huge programs are required. However, the situation is difficult to deal with when using current software technology. It is possible that the limitations of computer systems will obstruct the development of human society.

The new methodology developed by the project reforms the development and maintenance of software systems by changing the basic concept of software from foundation, and enables the development of a high-quality software system that can correspond flexibly to the diversification of needs and changes in social demand.

By promptly initiating the development of methodology, not only a smooth switch to the high-level information oriented society, but also an international contribution from Japan in software science is expected.

Advances in Industry

To design a new material, a new concept of the characteristics and functions of the new material and a new methodology to create the concept itself are required. A system to intelligently reuse the experience of designers and data that have been accumulated must be provided. However, it is difficult for industrial machines in the present production processes to adapt to changes in the environment flexibly, because behavior must be taught in detail beforehand.

The new methodology makes it possible for systematization of information from the huge data base, so advances in material design in the new material industry and bio-industry can be expected, and promotion of mechanization in a wide area such as intellectual work, and accelerated advance of industry achieved.

Advances in Science and Technology

Some systems such as movement of planetary objects in the universe, systems in mother nature such as energy and matter cycles in organic systems, and social systems operated by politics and economics, operate coherently as a whole by individual objects interacting without any centralized principles to govern the whole system. In present science and technology there is a reliability problem in analyzing, modeling, and predicting the behavior of such systems, because simplification and abstraction are inevitable in the course of modeling. Traditional analytical reasoning fails here. A method to deal with the architecture of composition instead of each component is required.

The new software methodology makes it possible to model those events in computers, making it possible to model social systems more appropriately. This will help science and technology to advance.

[DKK comments:

There are many aspects of the Software Structures project that sound similar to those expressed in the Real World Computing Program, another MITI sponsored activity. Indeed, there are probably researchers who would be comfortable working under the sponsorship of either. However, as far as I know, the projects are independent.

There are interesting computational projects supported under other AIST programs also. For

example, the Medical and Welfare Apparatus program includes research for "Three Dimensional Information Display Unit for the Blind" and "Digital Hearing Aids".

end DKK comments]

TRAVEL REPORT, 5th UNITED STATES/JAPAN WORKSHOP, 9-11 NOVEMBER 1992

D. H. Liebenberg

This 5th United States/Japan Workshop on High Tc Superconductivity was the first held in Japan. Tsukuba Science City was an appropriate location for this Workshop since the several science agencies in Japan have representation here. The Science and Technology Agency (STA) is the Japanese benefactor of the workshop, and the Department of Energy has been the U.S. benefactor. The arrangements made by our Japanese hosts included a full program that focused on bulk materials from STA supported activities.

The workshop was opened by Dr. T. Okazaki, Deputy Director General for Research and Development at the Science and Technology Agency. He noted the opportunity this workshop provided for the discussion and debate of current science research progress. Dr. S. Saitoh, President of the New Superconducting Materials Forum, welcomed us and noted the economic crisis in Japan that was causing re-evaluation of the program support. He viewed superconducting materials as the technology that opened the door to the next century. Dr. D. Shaw, U.S. workshop coordinator and Director of the New York State Institute for Superconductivity, welcomed us on behalf of Dr. Iran Thomas, Department of Energy, and noted that research support was not an entitlement but an investment for society at large.

The technical presentations were arranged to include plenary sessions and two concurrent sessions. Dr. T. Hasegawa was the first speaker and described work leading to a Bi material coil that generated a 1.5 Tesla magnetic field. She described the increase in critical current density Jc when the silver sheathed Bi(2223) wire was pressed rather than rolled and the decrease of Jc with core thickness. Maintaining uniform core thickness continues to be a problem, as is the rapid decrease in J_c with self or applied magnetic field for temperatures of 77 K, liquid nitrogen temperature. A 3-m long wire was used to wind a coil 54 mm in diameter with a 15 mm bore that had 96 turns and formed with eight pancake coils. Results for this coil in an applied field of nearly 20 Tesla and for both 4 K and 20 K temperatures were shown. At 4 K in a 14 T external field, 0.8 T were generated in the small coil. In zero external field the coil generated 1.5 T.

Dr. H. Kumakura reported the progress on a Bi(2212) phase tape prepared by a dip-coating process. The heat treatment schedule was described with 10 min at a maximum temperature of 885°C. J_c values decreased with the increasing thickness of the coating, and microscopic study showed the decrease of alignment in the Bi(2212) farther from the silver substrate. A problem of Bi evaporation during the heat treatment was noted. The technique of carrying out the heat treatment in an atmosphere of $Bi_2Al_{14}O_9$ was described. This treatment also improved J_c. Strain tolerance to about 0.2% was shown, and a double pancake coil of 14mm bore with 6.4 m tape length gave 1.6 T at 4.2 K in zero external field. At 21.5 K (liquid hydrogen temperature) the coil produced 0.7 T in zero external field. The need for a stronger substrate was noted; the Ag is annealed to a soft condition. More study is needed to determine whether the microstructure uniformity is adequate and to assess the dependence on thickness. While eliminating the second phase may be desirable, the second phase may also provide the pinning centers and the enhanced J_c.

Dr. J. Willis, Los Alamos National Laboratory, described Bi(2223) tape developed from the powder-in-tube, solid-state reaction, freeze-dried powder technology. Long time thermal processing was used, and the newer technique of jet-milling

produced average particle size of 2 μm. Lots of voids developed in the transformation of Bi(2212) phase to Bi(2223), so that secondary rolling and pressing was used to increase density. Magnetization measurements were made and showed loop collapse near 25 K, the irreversibility line. Results from American Superconductor Corporation Bi(2223) multifilament wire was presented. Currents of 240 A with J_c = 6000 A/cm^2 at 77 K were measured. Tolerance to 0.6% strain for this 9583 filament wire were shown.

Dr. M. Hiraoka, Mitsubishi Cable, described the efforts to make a silver sheathed Bi(2212) wire for application to a solenoid. This wire had a round shape with a ring shaped core of superconductor to promote orientation of the grains. The wire fabrication was described including drawing to 1 mm diameter. The single core wire showed more texture when the ring thickness was less than 100 μm. A seven core wire had improved J_c and I_c. Values of I_c to 160 A and of J_c to 0.15 MA/cm^2 at 4 K and 0 T were measured. The Ca, Cu deficiency of the material is selected to minimize Sr-Ca-Cu-O grains. Uniformity of I_c along a 600 cm tape was shown to be about 2% of I_c = 11.1 A. The mechanical properties are now under study.

Dr. M. Walker, Intermagnetics General, reported progress made on the dip coating process for Bi(2212) tape of 1 m length and 13 mm width. A 5 mm wide strip short sample carried about 80 A at 4.2 K as a two layer tape. Differences between a two layer exposed surface tape and a tape with one surface overlayed with a silver tape were not understood, although texture was observed to form predominantly in the first 30 μm thickness of the superconductor. [This has been well known since the report by Siemens - see D. H. Liebenberg and A. Clark High Temperature Superconductivity Research in Selected Laboratories in West Germany ONRL Report 8-011-R 8 July 1988.]

The Sumitomo Electric development of high Jc Bi(2223) wire was described by Dr. K. Sato. Their wire has a Tc of 110 K, clean grain boundaries and fine dispersion of nonsuperconducting phase material. They have produced 114 m length with J_c = 11,000 A/cm^2 that carries 14 A in zero field at 77 K. A strain tolerance of 0.18% was shown. A bussbar was described of 1 m length, 10 units of 20 tapes that carried 2,300 A with J_c = 5,300 A/cm^2. A 1.4 m long cable of a three multilayer react and wind tape carried 590 A with J_c = 7,020 A/cm^2 and showed no degradation with a 1.5 m diameter bend. A tape that showed I_c = 63.5 A at 77 K carried 136 A at 20 K and a 0.35 T field was generated with a coil of this material. The tape response to external fields of 20 T was measured.

Dr. D. Gubser, NRL, described his program that started with the criteria of a coil that produces 0.06 T at 27 K and improves the electric motor program of the Navy. He gave an overview of the Navy Consortium activities including the NRL high temperature superconductivity space experiment (HTSSE).

At this point two sessions ran concurrently and the report will emphasize the thin films. The author presented research work to determine the angular dependence of YBCO thin films fabricated at MIT by Professor M. Cima group by using a metalorganic nonvacuum process. Although the YBCO system is thought not to be so anisotropic as the Bi or Tl systems, the angular dependence fit well with the model of Tachiki and Takahashi for an anisotropic system modeled by a "brick wall" for vortex penetration near the field alignment along the a,b planes.

The first paper in the session described work in the advanced materials program. Dr. D. Nelson, National Science Foundation (NSF), noted the U. S. Government interest in the development of advanced materials and the multiagency effort planned. NSF emphasis on new classes of superconductors such as nitrides and sulfides, organics, and Fullerenes was described.

Dr. H. Koinuma, Tokyo Institute of Technology, discussed atomic scale fabrication of the perovskite oxides for substrates, thin films, and heterojunctions. Laser MBE (molecular beam epitaxy) techniques with RHEED (reflection high energy electron diffraction), a Ta heater for the substrate, and formation with oxygen pressure were shown to give a clean energy gap of 23 meV using STM (scanning tunneling microscope). At approximately zero bias dI/dV goes to near zero. An AFM (atomic force microscope) shows pedestal growth with a $\delta h > 10$ nm. An improved technique has reduced δh to about 0.12 nm.

Dr. K. Takahashi, Sanyo Electric, described a tunnel junction of Ba-K-Bi-O material with a thickness of 150 nm on an $SrTiO_3$(110) substrate with an MgO barrier of 2 nm and a gold overcoat of 200 nm. The variation of Bi content affects T_c and a temperature of 400°C is needed during MgO deposi-

tion to give epitaxial material. T_c = 27 K, the gap energy is 3.6 meV, and the junction shows low leakage.

Properties of an Eu-Ba-Cu-O film were described by Dr. H. Asano, NTT. The a axis films are susceptible to environmental degradation and have a roughness of 50 nm. Electron cyclotron resonance (ECR) cleaning is useful, since contaminants such as the carbonates are removed from the a axis film surface. He reported a surface resistance R_s = 100 R_s(c axis) measured at 50 GHz and values of the resistivity of 0.1 μOhm-cm at 77 K.

Dr. H. Obara, ETL, showed results of multilayer YBCO/PrBCO structures made with MBE using higher pressure ozone gas with differential pumping. One unit cell per minute deposition rate was used. A process to generate and liquify ozone and then evaporate it at higher pressure into the chamber was noted. [My note is to caution the use of this practice since ozone is a known energetic material, i.e., explosive.] The multilayer thicknesses can be used to control the anisotropy. Clean susceptibility transitions were shown at T_c = 86 K for these structures on an $SrTiO_3$ substrate. Critical currents for field parallel and perpendicular to the films planes were shown for fields to 15 T. A question was raised about the magnetic effect of the Pr ion; the response suggested the effect was small. The irreversibility effect of various layer thicknesses 4/4 unit cells or 8/10 Y/Pr were shown, the larger Pr thicknesses reduce the temperature of the reversibility line.

Dr. N. Schumaker, Emcore Corporation, discussed the MOCVD (metal oxide chemical vapor deposition) for superconducting thin films. N_2O is used as an oxidizing medium, and 0.1 nm/s growth rate for multiple 2 in diameter wafers can be obtained. At a frequency of 94.6 GHz more than 80% of the wafer has uniform surface resistance.

Professor T. Kawai, Osaka University, updated the reports he had recently made of higher temperature superconductivity in an infinite layer system, Ca-Sr-Cu-O. Bi_2O_3 layers can be inserted to make n=2 and n=3 layered systems. Additional oxygen is put in with NO_2. This extra oxygen is thought to be responsible for the increased T_c. Zero field cooled and field cooled magnetization curves show clearly a separation near 170 K. The resistivity curves show a dip against a generally rising curve with decreasing temperature such as a semiconductor. The lack of completion of zero resistivity has been observed in other superconducting materials, where a continuous path of the superconducting material has not been made. Estimates of only 1% of the 150 K material and 5% of the 125 K material were suggested. A phase diagram was shown. Log pressure vs Substrate temperature shows that the high transition temperature material occurs near a boundary between amorphous and crystalline material near T = 510 (C). Reproducibility has been established and in a desiccator a sample will keep for over two weeks. The challenge for others to show this high- temperature phase and increase its content is clear.

Dr. P. Aron, NASA, described space power systems and the potential for passive cooling to 60 K with a single stage radiator. Designs for a cooled tether cable were shown, and the weight advantages with passive cooling of the superconductor were described.

Dr. J. Tsai, NEC Corp., discussed his work in Fullerenes, including the BCS-like tunneling spectra that shows a gap of 8 meV. A summary of data from UCLA was shown, and the NEC results for ^{13}C substitution as well as ^{85}Rb to ^{87}Rb isotope shift were given. While the carbon substitution gave an exponent α = 1.4 from the equation $T_c = A^{\alpha}$, the value was zero for the Rb substitution, although the limit of accuracy, 0.2 K, may not be adequate to provide a definitive result. A Dayhem bridge was constructed with an I_cR = 10 mV.

Dr. J. Sato, Hitachi, described Tl and Bi tapes and applications. Tl(1223) tapes were made with a partial melt, solid state reaction, or new phase change sinter (PCS) method. The PCS material is more single phase and has fewer voids; the process involves heating to 950°C with a self-solvent. At 77 K the J_c values are above 10,000 A/cm^2, greater than values obtained with the other process methods. The hysteresis loops were shown and the PCS loop is smaller. The Bi(2223) tape is made by extrusion, a composite billet is made with a silver to superconductor ratio of 5.8:1. The Tl(1223) tape appears to have better qualities than Tl(2223) or Bi(2223).

Dr. G. Whitlow, Westinghouse, described his efforts to produce Bi(2212) wire and tape. An optimization of heat treatment was developed to give a 0.060 in diameter wire an I_c = 550 A and I_c = 240 A at 3 T. J_c increases with the higher cooling rate. HIPPing (high pressure processing) was described to produce J_c = 50,000 A/cm^2, somewhat less than for the wire above. An Ag/Pd alloy sheath with higher melting point to increase strength of the sheath after annealing was developed, and such wire, not yet optimized, has I_c = 170 A at 0 T and 4 K.

Also, 49 filament wire was described, but the I_c was lower, 40 A. Multilayer ribbon conductor by painting Bi(2212) on silver tape, gave a very homogeneous superconductor region and I_c = 200 A for four layers, and 100 A at 3 T at 4 K. The tape is robust to thermal cycling, although the wires seem to carry higher current, which Prof. Clem suggested might be due to geometrical effects.

Dr. Hayashi, Kobelco (Kobe Steel), described his silver sheathed Bi(2212) wire for magnet application. Kobe Steel has worked to produce a superconducting joint by using two methods that involve stripping back the sheath to make superconductor to superconductor contact. The I_{cj} is measured across the joint and compared with I_{cn} along an undisturbed part of the tape near the joint. The largest reliable value of I_{cj} is obtained for the ratio I_{cj}/I_{cn} = 0.62, when I_{cn} is kept small. But I_c = 100 A has been measured in zero field with a rapid decrease to 30 A for small fields. The traveling solvent floating zone (TSFZ) produces large single crystals of Bi-(2212) that were shown and will be displayed at ISS'92. Ion irradiation with Ti, N ions at 70 keV were shown to increase the irreversibility line in the temperature range 23-30 K from 1 T to 3 T. They have produced 1.6 T field in a coil at 4.2 K that operated at 290 A. They noted that stability to decay was obtained for current densities of $0.24J_c$.

Dr. D. Van Dollen, EPRI, described his program of basic materials studies and two banner programs; cables and motors. The ASC conductor was noted and the work with Reliance Electric for the motors was described. The banner projects have recently been reauthorized; a HTS cable installation (in 1993) for testing to 2000 and a 1 HP motor development and 5000 HP design.

Dr. T. Maeda, Furakawa Electric, has used a jelly roll process of 11 layers to develop Bi(2212) material with high orientation and $J_c \sim 35{,}000$ A/cm^2 at 77 K. I_c = 325 A at 4 K and at 10 T I_c = 112 A. The solenoid coil develops 1.06 T at 4 K with a 10 mm ID and quenches at 287 A. A Bi(2223) silver sheathed multilayer tape was developed for 77 K by using a react and wind technique. Thirty tapes are combined for a block, and 13 blocks are placed around a stainless-steel core in a 1 m length. This assembly carries 1500 A/cm^2 with I_c = 1825 A and has a 50 mm OD. Bare Bi(2223) rods have been tested as current leads for magnets, and a pair of such rods has been operated between 4 - 50 K to carry 1300 A through a NbTi superconducting wire at 4 K.

Dr. R. Poeppel, Argonne National Laboratory, described his program with Bi(2212) and Bi(2223) silver sheathed tapes. A powder packed tube, draw, and roll process was used. Compressive stress is obtained from drawing. Values of $J_c \sim 10{,}000$ A/cm^2 at 4 K for Bi(2212) and 30,000 A/cm^2 at 77 K for Bi(2223) with mixed second phase of Bi(2212) were reported.

The Fujikura results were reported by Dr. O Kohno who described the Jc enhancement in a biaxially aligned YBCO film on a buffered metallic substrate. With MITI support they have obtained Jc $\sim$ 1000-10,000 A/cm^2 at 77 K, 0 T for films on YSZ buffered Hastelloy C276. Ion assisted sputtering is used to treat the YSZ substrate of 80 nm thickness to be biaxial as shown by the pole figures. Then for laser ablation of the YBCO, the underlying substrate of YSZ controls the texture. The highest J_c occurs for the smallest pole figure spread. The grain boundaries have a 7-14° spread.

Vortex dynamics studies were emphasized at this workshop, and the work of Dr. K. Kadowaki, NRIM, began this section. He noted that Bi single crystals show different resistivities vs temperature dependent on the direction in the crystal, the lowest curve for the b axis direction. Broadening occurs in an applied magnetic field. A matrix of theoretical and experimental results for the resistivity independence of the Lorentz force was shown for a,b and c directions. For B // I // c the angular variation shows resistivity dips at 90° with enhancement at fields to 3 T, 77 K. The ratio of resistivities along c and a,b axes is 10,000 to 300,000, and the coherence length ratio a,b/c is about 100. The magnetization vs H curve shows an additional peak (so called fishtail). These results were discussed in terms of the pancake vortex model and the phase diagram given with regions above the Meissner region for a nonzero J_c and J_c = 0 fluctuation region. At higher temperatures and fields, the planar vortices decouple.

Professor J. Clem, Iowa State University, described his 2-D pancake vortex model and flux pinning. The theory is extended from the Ginzburg-Landau theory. He obtained results when the Josephson coupling can be neglected and when it must be included. He gave an example of pinning by damage tracks. And he noted that for the coherence length less than the lattice spacing was a case when Josephson coupling can be neglected and the Hcos(Θ) relationship obtained.

Research at Tohoku University was described by Prof. N. Kobayashi on the anisotropy of YBCO

single crystals. The angular variation of calculated pinning energy showed a peak at 90° that was independent of applied field, while the variation at 0° was very field dependent between 1.5-4.5 T at 30 K. Intrinsic pinning at 90° and twin boundary collective effects were presented as explanations.

Prof. A. Zettl, University of California, Berkeley, discussed transport in Bi(2212) and Fullerenes. He proposed a fit to his resistivity vs T and H data with the Ambegaokar-Halperin weak link model. Other models have been used by others, an order parameter fluctuation and Josephson junction stacks. The experimental results for Bi(2212) were contrasted with those for the Fullerenes that are described with a 3-D conductivity for both the potassium and rubidium systems.

Dr. H. Yoshino, Toshiba Co., described the pinning of a axis grains in a c axis oriented YBCO film. Possible pinning centers were suggested such as screw dislocations, stacking faults, precipitates, strain, and twins. A metal source sputtering technique produced films with Tc ~ 87 K and J_c ~ 0.13-0.22 MA/cm^2. The angular dependence of Jc was shown with fairly broad peaks at 90° (H//a,b) and a small peak near 0°.

Prof. B. Maple, University of California, San Diego, discussed flux motion and pinning in the YPrBCO and Sm-Ce-Cu-O systems, p and n type respectively. The irreversibility line was determined, and the phase diagram of Tc with fraction of Pr. Since a small Pr addition doesn't change Tc much, he suggests that Pr could act as pinning centers to increase Jc.

Dr. H. Ikuta, University of Tokyo, Prof. Kitazawa's group, discussed a very interesting new observation of giant magnetostriction in Bi(2212) single crystals. A capacitance measurement is made of $\delta L/L$ ranging to -0.0002 at 6 Tesla with the field parallel to c axis and at 4.8 K. After one cycle the zero field value has not returned to the initial value. Flux entry produces a compressive force providing a possible explanation. The time dependence is under study.

Dr. M. Suenaga, Brookhaven National Laboratory, discussed flux pinning and the increase of I_c with heavy ion irradiation. Stopping power was noted to be important, variations by a factor of ten occur between Si and Au. For Tl(2223) J_c increase and the irreversibility temperature increases with irradiation. The strain induced around the defect is important. Damage along stacking faults may reduce diffusivity.

Dr. M. Okada, Hitachi, showed field dependent data of J_c for Tl(1223) and Tl(2223) at 77 K. The Tl(1223) J_c value held up better in fields to 10 T suggesting a 3-D vortex structure while Tl(2223) fit better with the 2-D pancake model. A brief mention was made of YBCO(123) tape development that included melt texturing.

Dr. J. Thompson, Oak Ridge National Laboratory and University of Tennessee, discussed melting and flux creep with irradiation induced defects. Proton irradiation of 6 x 10^{15} cm^{-2} showed J_c increased to about 10 MA/cm^2 and with applied field first increased and then decreased.

Finally Dr. Y. Kazumata, Japan Atomic Energy Institute, discussed radiation effects in La-Sr-Cu-O. At low voltages, cluster defects were formed but above 2 keV/Angstrom columnar defects formed. No change in T_c was found for 3 MeV electrons with dosage of 2 x 10^{13} cm^{-2}. Magnetization is reduced for H along the a,b plane and increased slightly for H parallel to the c axis.

Although I missed the Monday afternoon parallel session on Phase Equilibrium and Processing Issues for Bulk Materials (six each U.S. and Japanese papers), several of the Japanese papers were reported in the subsequent site visits. One paper that was not the work of Prof. K. Tachikawa, Tokai University and former Director of NRIM, reported further work on the diffusion process for synthesizing high temperature oxides. His plan is to apply the approach so successfully developed by him for the Nb_3Sn diffusion process with metals. The U.S. delegation members expressed optimism about the accomplishment of his plan.

In summary, at this meeting a number of details about the processing of bulk Bi(2212) and Bi(2223) materials were obtained and related to the transport properties. As important was that at several laboratories the Japanese have accomplished the production of enough wire material to have coils fabricated able to produce well over 1 Tesla fields—the maximum of 1.6 Tesla is quite significant. The issue of which bismuth phase is most useful has not yet been settled. There was further work on the thallium and YBCO systems, the latter still the most likely choice for operation at 77 K and magnetic fields above 2 T. The giant magnetostriction reported by the Kitazawa group is certain to stimulate further work in both countries, and the possibility of new devices will also be assessed. Radiation effects are being better understood and continue to be important for space applications and for the prospect of increased

pinning, especially in the bismuth systems. Vortex dynamics theory and experiments are critically challenging each other with benefits for both groups. Although Japanese industries are experiencing a recession with some layoffs and about 15-20% of last year University graduates did not receive offers of work, the Japanese commitment to superconductivity still remains very strong.

TOUR OF JAPANESE LABORATORIES ARRANGED AS PART OF THE UNITED STATES/JAPAN WORKSHOP ON HIGH TEMPERATURE SUPERCONDUCTIVITY

We visited the National Research Institute for Metals (NRIM), one of the best laboratories in the STA supported research facilities. Tsukuba engages about 430 people with an estimated U.S.$54M (U.S.$27M for direct support without salaries) in several projects. The 40 Tesla hybrid magnet has a new design for the NbTi and $(NbTi)_3Sn$ coils that involves a hard copper outer sheath with a gap to reduce the stress on the interior superconducting windings. A 15 T superconducting coil is operated at superfluid helium temperatures and has a 40 cm bore. The bore is filled with either a Cu-Al_2O_3 25 T coil to give 40 T in a 3 cm bore or a 20 T coil of Cu-Cr, Cu-Al to give 35 T in a 5 cm bore. The 25 T magnet is a water cooled polyhelix with a 1 MW power supply and cooling power system. The 40 T magnet is expected to be ready as a national magnet for experiments in about two years. The second project is a 20 T large bore superconducting magnet. A sequence of four coils, the outer magnet operating at 4.2 K carries 4717 A. The inner coil carries 857 A and together the four coils take 100 l/hr liquid helium. A third project is the 80 T long-pulse magnet we saw in the early stages of testing. The capacitor bank will deliver 1.6 MJ at 5 kV and 128 mF. They are also developing a new alloy that will have the required strength and homogeneity in the wire. Their present use of Cu-Nb is nonhomogeneous and develops resistive hot spots and failure.

Dr. Maeda also described the effort to develop Nb_3Al material since it has lower strain sensitivity. He hopes to commercialize this material, and he described the dip coating method for preparing Bi wires and the silver alloy to give improved strength to the annealed wire (as discussed at the workshop).

We visited the National Institute for Research in Inorganic Materials (NIRIM) the same day. They employ 165 people and place emphasis on ceramic materials. Superconudctivity research receives about U.S.$5M for support. They have studied the superoxygenated YBCO system and found that Tc does not increase. A new compound $YSr_2Cu_3O_4$ was prepared under pressure (6 GPa), which has a $T_c \sim$ 60 K onset. The $La_{1.7}Ca_{1.5}Cu_2O_4$ compound was described as superconducting without the Sr addition (onset near 70 K). They have tried doping the infinite layer system and through their work have identified that many further studies on the T, T', and T* systems must be made. A carbonate superconductor (discovered at NTT), $(Ba_{1-x}Sr_x)_2Cu_{1+y}O_{2+2y+z}(CO_3)_{1-y}$ was worked on, and it has T_c = 40 K with x = 4/9, y = 1/9. They have analyzed the Bi(2201) phase incommensurate structure to show the modulation. Their very impressive 1.5 MeV atomic resolution TEM was shown with work that is coming from it. The oxygen atoms can be seen with this instrument, and thus they are making unique studies of oxygen ordering at the atomic level. A 1 Å resolution is obtained in a 2 s exposure. We also saw the significant effort devoted to diamond synthesis and thin diamond film fabrication. They have succeeded in making an n-p type diode with the boron nitride material that they are also growing. The 30,000 t press for this work was made by Kobe steel and assembled on site.

At the NEC Research Laboratories in Tsukuba, Dr. H.Igarashi, Research Manager, was our host. This Laboratory is staffed with 370 people (230 researchers) working on several thrusts.

The company supports at several laboratories around the world including Princeton, NJ, laboratory. They showed us an SNS junction with gold, Bi(2212), Bi(2201), Bi(2212) on a Bi(2201) buffered $SrTiO_3$ substrate. A 10 nm buffer thickness is needed to reduce second phase formation in the Bi-(2212). The junctions are 20 μm square. The insulator layer is 20 nm thick, and the resulting I-V curves suggest that there are no pinholes. I_c = 240 μA and I_cR = 0.24 mV at 4 K. The junction activity is measurable to 50 K and Shapiro steps are seen as well as interference in a magnetic field. He also showed us the work on Tl(2201), which is a hole overdoped material. The inverse Hall mobility is linear in T^2 and agrees with P. W. Anderson's theory. Overdoping decreases the T_c. Dr. Tahara discussed their continuing low Tc Josephson junction (JJ) compute interest. They have made a 4k RAM with Nb technology that operates at a 580 ps cycle time and takes 6.7 mW. The 6 mm size chip contains 25,000 JJs. Planarization has been applied.

Chip bonding with 25 μm size Pb-Sn "bumps" was shown. Electrochemical deposition was used to fabricate the bumps. They can not adequately test the chips because of the noise problems with their standard test instruments developed for silicon technology. Their plans are to extend this effort on company funds to a 0.5 μm design rule with 1 μm sized JJs. This seemed like a most interesting development, since the formal MITI project ended more than a year ago.

They discussed their C_{60} work and the disagreement in isotope shift measurements between their laboratory and Bell Labs. Their value of alpha is 1.3 and much larger than reported for ^{13}C substitution elsewhere, although they noted a recent paper by C. Lieber, Harvard, that gives a value larger than Bell or UCLA. They have also made nanotubules that seem to be ~10 nm in diameter (as suggested by STM measurements) and up to microns long. They have been able to optimize the production. Their new STM operates at 10 K and in high vacuum (10^{-10} Torr) and is equipped with a portable high vacuum chamber for transporting samples.

Our visit to ISTEC was hosted by the Director Professor S. Tanaka. He arranged a program of talks given by each of the division heads. They are expecting an increased budget for next year in anticipation of reorganization that will probably include greater emphasis on supporting product development. The number of researchers total about 100 including 76 postdoctoral and graduate students supported by member companies. Only four (plus the division heads) are permanent. The budget was discussed and shows an increase by MITI of about U.S.$7M in FY93, while there is a small decrease in STA support and constant but small support by the Ministry of Education. The MITI increase comes for increased support in power applications.

Significant increase in the performance of the MPMG (melt processed melt growth) material of Professor Murakami was described. The I_c at 10 T and 4 K was 88,000 A/cm^2 and at 10 T and 77 K was 24,000 A/cm^2. They are now polishing a sample 10 cm on the diagonal. The crystal orientation can be controlled with the thermal gradient in two directions. A flywheel operating at 1200 rpm with a 1 Whr storage will be demonstrated at ISS'92. For a 1 MWhr unit the design suggests it will be 4 m in diameter, 100 ton, and requires 30,000 MPMG elements. The efficiency would be the same as for the small unit, 10 Whr/kg. Their interest in microwave components is related to the mobile communications and the need for fine frequency control with little loss. Mixers and resonators at 25.6 Ghz are being made. They also showed a concept for integrating these components with GaAs semiconductor technology.

A large single crystal of YBCO has been made by a crystal pulling technique involving details that were not released at this point. The crystals were 7 by 7 mm and had a length of 17 mm of new growth beyond the seed. The crystals will be shown again at ISS'92. Professor Tanaka noted five major points of current/future interest:

1. high Tc materials development,
2. study to increase pinning centers in Bi, Tl materials,
3. multilayer thin film deposition,
4. research on interfaces and surfaces,
5. improved fine pattern lithography.

Flux dynamics and pinning were discussed by Dr. N. Koshizuka, Div. I. Very nice magneto-optic pictures of flux pinning in Bi(2212) were shown and the flux avoidance near a grain boundary was counterintuitive but consistent with the picture of nearby strain acting to pin the flux away from the boundary. NMR and NQR techniques were being applied, and in YBCO(124) the $1/T_1T$ vs T curve shows apeak at 150 K and shifts to lower values with Ca doping.

Dr. H. Yamauchi, Div. II, discussed high pressure techniques to produce the infinite layer compound. $(La,Sr)_2CaCu_2O_6$ was made superconducting under pressure with T_c = 50 K. Structure studies were carried out with Dr. J. Willis, Los Alamos National Laboratory. They have not yet produced films with zero resistance by laser ablation. In the Tl(2223) system they have raised $T_{c(onset)}$ to 130 K and $T_{c(R=0)}$ = 127 K; results that have been reproduced elsewhere now.

Dr. Y. Shiohara, Div. III, described the chemical processing, single crystal growth, and MOCVD techniques for film growth. The YBCO crystal mentioned by Prof. Tanaka has a T_c ~ 90 K and was drawn with a SmBCO seed that has a slightly higher melting temperature than YBCO. Pulling rates were uneven but not more than 0.1 to 0.05 mm/h.

Dr. T. Morisita, Div IV, discussed physical processing of thin films by dc to 100 MHz sputtering, a laser ablation system, and studies of film growth with RHEED. The Y_2O_3 crystal has been grown as a low dielectric constant substrate material. Also an La-Nd-Ga-O material can be tuned with Nd to match the YBCO lattice. The rocking curve shows

a spread of 58 arc-s for the substrate and 72 arc-s for the YBCO overcoat, although the T_c is low (30-40 K). They are continuing work on this material.

Dr. Y. Enomoto, Div. VI described device applications, their 13.3 GHz filter with 0.2 db loss at 16 K and the step edge junction with I_cR = 0.8 mV at 10 K. Dr. Murakami discussed further experiments on levitation, a 2.4 kg rotor at 30,000 rpm is planned. He has never seen flux jumps in the MPMG material at 77 K but has seen flux jumping at lower temperature.

The visit to Kobe Steel was hosted by Dr. T. Horiuchi, Technical Director of the New Business Division. He noted that greater effort is needed in materials development to provide for practical applications. And he supported the United States/Japan collaboration on materials. The Kobe Steel Co. Kobelco has made an effort in superconducting wires since 1965. Dr. R. Ogawa, Chief Researcher, noted plans for construction by Kobelco of the longest suspension bridge and the six operating divisions: iron and steel, aluminum and copper, cutting tools, welding, engineering and machinery, and new business. They are also producers and designers of helium liquefiers as Mr. Miatake pointed out. He noted that because of continuing improvements on the low temperature superconductors they should not be called classical. Higher field NMR magnets, to 10 T, are planned with NbTi and above 10 T with Nb_3Sn. A 55 filament wire is produced with a ratio Cu/NbTi of 1.4. Lower field wire for MRI magnets less than 2 T are fabricated with 24 filament 70-100 μm size and Cu/NbTi = 6.4 for quench resistance. A Nb_3Sn wire with a ring core around a Cu core was described. A powder metallurgy process can give wires suitable for 60 Hz use. And $Nb_3(Al,Ge)$ wire is under development since $H_{c2} \sim 40$ T.

Dr. S. Hayashi, Senior Researcher, described the oxide superconductor work. We visited their laboratories and saw the coil of the Bi(2212) that produced 1.6 T at 4.2 K with I_c = 290 A. The joints were discussed again. Single crystals were examined with high resolution microscopy; YBCO(124) with Ca doping had T_c = 80 K. And SEJJ (step edge Josephson junctions) were shown of YBCO/MgO operating to 70 K at 110 GHz. In a most impressive demonstration they were using a junction in a receiver network to provide satellite television to a set in the laboratory. The unit was working at 4 K but made a very nice demonstration.

Mr. R. Hirose discussed the MIT collaboration on a 750 MHz high field NMR magnet using MIT design and construction and Kobe wire. The coil is planned to produce 17.63 T at 4.2 K and drift less than 0.01 ppm/h. A high field magnet of Nb_3Sn/NbTi will use 1.8 K superfluid helium and produce 19 to 20 T with an insert coil. They are producing a horizontal bore magnet for biotechnology research, and he showed results of increased bacterial reproduction rate in a 7 T field.

Dr. K. Takabatake, JMT (Japan Magnet Technology) a subsidiary of British Magnex marketing superconducting technology, acknowledged the difficulty of developing markets for profit at this point in time. An RBS system with 1 μm spot size and good shielding was shown during the tour. Diamond films grown with grain size 1-3 μm were shown on 2 in wafers of silicon and were etched with oxygen ions. A filament deposition technique has been tried but shows tungsten impurity in the diamond films. A rectifying diode of diamond films was demonstrated. Very recently a laboratory for microwave high-temperature superconducting components was established; this is where the JJ demonstration took place.

Our tour to Mitsubishi Heavy Industries to view the Yamato I, the MHD propelled boat, was the last stop of this tour. Dr. J. Namba provided translations from the chief engineer. The ship was launched Jan. 27, 1992, and first thruster trials were June 16, 1992. These tests were completed near the end of August, and the boat is now in dry dock where we saw it. The specifications are by now well known, six dipole magnets with 4 T field cluster to form one thruster. Two thrusters are independently controlled. The field is established by an on-shore charging power supply, and the speed is controlled by the electrode current supplied by diesel engines on board. The liquid helium cooled magnets are again prepared at on-shore facilities and then maintained by Kobe designed and built micro-refrigerators that use a high speed miniature turbine (about 2-4 mm diam). Sea trials were conducted to 3 T that gave 6.6 knots for water speed in the thruster. Hydrolysis of the water gave hydrogen and oxygen bubbles that would appear to this writer to offer additional potential thrust by controlled catalytic burning. Electrode current for this speed was 1800 A. The electrodes have 100 h of operation and are not corroded; they are of a U.S. patented titanium alloy. No plans have been made for a Yamato II since it was determined that Yamato I represents the best technology avail-

able; superconducting technology first must be advanced.

These tours provided a significant addition to the United States/Japan Workshop. The U.S. delegation was asked to assess the need for continuing this workshop, and we met after the formal presentations in Tsukuba. While support for continuation was given, especially if the frequency is reduced to biennial, and each country takes turns at hosting the meeting. I'm convinced that the support would have been stronger from the U.S. delegation at the end of the tour. Both the opportunity to see the level of equipment and personnel support in addition to the opportunity to develop personal relations with investigators at their institutions represented a substantial positive contribution of this workshop.

Dr. Donald H. Liebenberg received B.S., M.S., and Ph.D. (1971) degrees from the University of Wisconsin in physics. A staff member at Los Alamos National Laboratory for 20 years (until 1981), he carried out research in the areas of low temperature physics, high pressure physics, and solar physics and contributed to major laboratory programs such as Rover (the cryogenic fluid propellant nuclear rocket reactor) and the laser fusion program where he was on the technical staff of the project director's office. Some 100 technical publications resulted from these investigations including the first application of fluctuation theory to the problem of superfluid belium film flow, the determination of the solar coronal temperatures and line-of-sight turbulence structure from precision spectroscopic measurements, and the initial studies of gases at high pressures in a diamond anvil cell. As Program Director for Solar Terrestrial Physics (on rotation to the National Science Foundation in 1967-68) and later as Program Director for Low Temperature Physics (1981-88) Dr. Liebenberg was instrumental in obtaining submillikelvin research support and facilities and in supporting high temperature superconductivity discovery research. He joined the Office of Naval Research, Physics Division, in 1988 as Scientific Officer in Condensed Matter Physics. This program supports basic research in high temperature superconductivity, quantum transport in disordered systems, and correlated electron systems. Dr. Liebenberg is a member of the American Physical Society, American Astronomical Society, American Geophysical Union, American Association for the Advancement of Science, and the Cosmos Club of Washington.

2ND INTERNATIONAL CONFERENCE ON FRONTIERS OF POLYMERS AND ADVANCED MATERIALS

This article is about the 2nd International Conference on Frontiers of Polymers and Advanced Materials (ICFPAM), Jakarta, Indonesia, January 1993. Emphasis is on research progress in the development of polymers for optical applications and on surface polymer chemistry and science.

Kenneth J. Wynne

INTRODUCTION

The 2nd International Conference on Frontiers of Polymers and Advanced Materials (ICFPAM) was held in Jakarta, Indonesia, 10-15 January, 1993. This conference followed the First International Conference on Frontiers of Polymer Research held in New Delhi, India, in January 1991. The goals of ICFPAM included:

a. Global representation from the highest levels of industry, government, and academia,
b. A focus on global strategies on interfacing advanced materials and emerging new technologies,
c. Balanced emphasis on science, technologies, and business opportunities,
d. Opportunities for joint ventures and collaborative programs.

The conference was held at the Grand Hyatt Hotel, Jakarta, a modern five star hotel with excellent accommodations. The conference was attended by 166 participants from 22 different countries. Countries with more than five conference participants included France, Germany, Indonesia, Japan, Korea, Sweden, Switzerland, Thailand, and the United States.

The conference cochairmen were Professor Paras N. Prasad, Director, Photonics Research Laboratory, Department of Chemistry, SUNY Buffalo, and Professor Dr. Samaun Samadikun, Chairman, the Indonesian Institute of Sciences, LIPI, Jakarta, Indonesia.

In the context set by the meeting organizers, the conference goals fit very well with the emergence of Indonesia as a major power in the Pacific Rim. Indonesia's oil and latex resources lead logically to the development of a polymer industry with its higher valued added products. Thus, this first international conference on polymers and advanced materials was an important event and received the attention of the Indonesian Government at the highest level. This was reflected in the opening ceremony of the meeting that was held at "Bina Graha" the State Palace, two miles from the meeting hotel. The "Meeting Inauguration Address" was given by His Excellency President Soeharto. The importance that the President attached to his presence at ICFPAM was underscored by two circumstances. First, bound copies of his address were provided to each attender. Secondly, the President fully participated in the opening ceremonies despite a scheduled visit of the newly elected Prime Minister of Japan to Jakarta shortly thereafter. The participation of President Soeharto made a great impression. Many attendees felt it was indicative of a major commitment by the Government to improve the infrastructure in research and education in the sciences in Indonesia. In his address President Soeharto noted that Indonesia already has a polymer industry, but that it is directed at conventional materials. The President wishes to build upon this base, and stated that "We are aware that polymers are extremely important materials for economic growth and sustainable development," and further that "We hope we can enhance our ability to master science and technology needed for the development

of a polymer industry." This effort is part of a "Second Long-Term Development Program" (25 years) whereby Indonesia will "use and develop more sophisticated technology, and will continue to intensify the effort to develop relevant scientific and technological infrastructure for modern industries."

The President's address was followed by that of the Honorary chairman for the conference, Professor Dr. Ing B. J. Habibie, Minister of State for Research and Technology, and Chairman, Agency for the Assessment and Application of Technology. Professor D. Habibie welcomed the program participants and noted in his address the various efforts to develop the scientific and technological capacity of Indonesia that are in progress. He emphasized the importance of expanding "the indigenous technological knowledge and capability in the areas of advanced materials in general, and frontiers in polymers in particular."

Continuing the opening ceremonies, Professor Samadikun, conference cochairman, expressed well the driving force behind the organization of this conference and its goals in his message to the participants: "The growth of polymer related industries in Indonesia is creating a conducive atmosphere and opportunities for the development of indigenous polymer research activities." and further "It will be a global representation of industry, government, and academia, which the Indonesian polymer community can exploit to improve its knowledge and to make linkages with the world's polymer community."
In conclusion to the opening ceremonies, Professor Prasad, conference cochairman, added in his message that "Our host country is important strategically in the Pacific Rim Region and Asia, and is also the world's second largest producer of natural polymer."

POLYMER EDUCATION

In addition to the technical sessions where research papers were presented, sessions on Polymer Education and Business Opportunities were also given. The latter sessions were designed to share information about how polymer programs around the world were developed and how they operate. Professor N. M. Surdia, Bandung Institute of Technology, speaking for the host country, pointed out the rich resources of Indonesia. He emphasized that the presence of oil and rubber is no guarantee for economic growth if the raw materials cannot be processed into materials and manufactured goods for the domestic market. He noted that in the next planning period "the second long term national development of Indonesia" greater emphasis will be given to economic growth through materials processing industries. For this reason, he talked of the need for education in materials science and technology at the university level in Indonesia.

As an example of the implementation of this strategy, Dr. J. Enoch talked about the preparations for the establishment of a professional school of rubber technology by the Indonesia Rubber Foundation. The latter, which is called "Yakindo" in Indonesia, recognized the need for human resources, which would be required for the increasingly sophisticated analytical and physical methods required for improving Indonesian natural rubber. The result of a task force study is a planned curriculum for a Diploma in Rubber Technology aimed at problems in manufacturing technology.

In a similar vein, Professor K. Mongkolkul, Director, Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand, addressed the history of his newly established College. A masters program in polymer science and petrochemical technology is being initiated in April 1993. He noted that "The key strategy of the College to achieve the desired high international standard is to ... establish academic partnership with three U. S. university departments that have world renown expertise in the subjects." The plan is to graduate 40 highly qualified engineers and scientists per year to serve the polymer and petrochemical industries and technical institutions in the Pacific Rim countries. In addition, Professor Mongkolkul hopes to establish the college as one of the regional centers for frontiers in polymer and advanced materials research.

Subsequent talks at this session were given by faculty members from Germany, the United States, and France, where major schools and departments exist that are dedicated to polymer chemistry, physics, materials science, biomaterials, and engineering. Professor Claus D. Eisenbach, Macromolecular Chemistry, University of Bayreuth, Germany, outlined programs in teaching and research offered at German universities as part of the course of studies in chemistry at the undergraduate and doctorate levels. Professor Eli Pearce, Polymer Research Institute, Polytechnic University , Brooklyn, NY, noted the designation of advanced materials as a Critical Technology in the United States. He focused on the importance of polymer science in this context and its interfaces with other fields.

BUSINESS OPPORTUNITIES

One of the interesting features of this meeting well matched to the emerging growth of Indonesia was a session on business opportunities. This session consisted of presentations by Indonesian industrial scientists and those of other nations. This format allowed for sharing of the status of a number of relevant fields and an assessment of future needs.

A presentation on "Latest Developments in the Polymer and Plastics Industry in Indonesia" was given by Dr. M. S. Ratulangi, a Petrochemical Consultant from Jakarta. He pointed out the progress in the last 25 years in Indonesia and noted the important role of polymers and polymeric materials in this growth. This talk focused on the role of polymeric materials in terms of historic trends in production, domestic use, exports, and contribution to the gross domestic production. Dr. N. Kahar then gave a talk on capacity building of polymer research in Indonesia. He noted that the linkage between polymer science and technology research activities with the polymer related industries is still very weak in Indonesia, and that it needs to be established. However, government research and development institutions are trying hard to direct their activities to support industrial development. Efforts to formulate strategic directions for polymer research activities and to promote inter R&D institution networking is ongoing and still in the early stage of the learning curve. Dr. Kahar stated that international cooperation in polymer science and technology will play a key role in the development of these areas in the future in Indonesia.

These and related presentations with the exhibition booths, through which industrial organizations could explain their products and capabilities, produced a stimulating climate for discussion and cooperation in areas such as membrane technology for water purification and the development of the polyvinyl chloride (PVC) industry.

TECHNICAL SESSIONS

In addition to polymer chemistry and science, ICFPAM included coverage of materials chemistry topics such as "bucky ball" (C_{60}) containing structures and aspects of solid state chemistry. A broad spectrum of polymer chemistry and science was covered including the following topics:

- High Performance Polymers;
- Polymers for Photonics;
- Polymers for Electronics;
- Polymers for Biotechnology;
- Polymer Processing;
- Advanced Materials from Natural Polymers;
- Polymer Blends and Composites; and
- Polymer Surfaces.

This article focuses only on some of the topics covered in polymer chemistry.

SURFACE POLYMER SCIENCE

The author was on the International Advisory Committee for 2nd ICFPAM, and also helped organize and was symposium chairman for "Polymer Surfaces", a half-day symposium. The session was opened by Professor J. J. Pireaux, University of Notre-Dame de la Paix, Interdisciplinary Laboratory for Electronic Spectroscopy, Namur, Belgium, who obtained vibrational spectroscopic data by using HREELS (high resolution electron energy loss spectroscopy). In this method, a high energy electron beam impinges on the sample, and the scattered electrons are analyzed to determine energy loss. Because a fraction of the electrons that interact with the sample experience energy loss through interaction with vibrational modes, part of the energy loss spectrum reflects the vibrational spectrum of atoms near the surface.

This technique is very sensitive to surface composition, as the depth of analysis is only about 20Å. This is shown by an experiment wherein a monolayer of deuterated PMMA (DPMMA) was overcoated with successive monolayers of normal PMMA. The C-D and C-H stretching modes are clearly separated and observed with up to two monolayers of PMMA over the initial monolayer of DPMMA. But after three monolayers of PMMA are coated over DPMMA, the C-D stretch is no longer detected. Thus, interrogation depth is about 20-25 Å and the sensitivity to the chemical nature of the surface is a major advantage for this technique.

In favorable cases, the very high surface sensitivity of HREELS allows the analysis of orientation of functional groups at the polymer surface. Figure 1 shows the structure of the polyimide PMDA/ODA, which is derived from the reaction of poly(pyromellitic dianhydride) and 4,4'-diaminoph-

enyl ether. This polymer is used in thin film electronic materials as a high temperature insulating layer. By examining the angular dependence of the C=O absorption, we can see that the maximum intensity corresponds to an in-plane orientation of the PMDA portion of the structure. In contrast, analysis of the C-H stretching region reveals that the phenylene ether portion of the structure is oriented out of the plane of the surface, with an average angle of about 65°. Furthermore, when aluminum is evaporated onto PMDA/ODA films, the C=O absorption is attenuated relative to other absorptions, suggesting that Al bonds to the C=O portion of the structure.

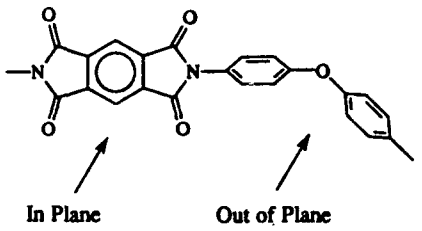

Fig. 1 — Structure of the polyimide PMDA/ODA

HREELS thus offers a wide range of information about polymer surfaces and interfaces. However, because most polymers are insulating, the interaction of the electron beam with the polymer produces charging effects. Such effects can greatly alter baseline spectra. Thus, for this technique to be successful, the polymer sample must be rather thin (300 Å), and the film must be formed on a very smooth conducting substrate. Furthermore, surface sensitivity of different vibrational modes is not easily quantified.

Dr. Michael J. Owen, Dow Corning Corporation, Midland, Michigan, gave an overview of new developments and global trends in surface-active low-surface-tension materials. He emphasized organosilicon containing polymers. He described new work on siloxane polymers of general formula $\{CH_3(R_f)SiO\}_n$, where R_f is a partially fluorinated side-group. Preliminary measurements of the surface free energy show that the presence of the fluorinated substituent on silicon has an important effect on the surface free energy. The surface free energy for poly(dimethylsiloxane) determined by the method of Owen and Wendt is found to be 24 mN/m. For a polymer of the formula shown above with R_f = $CF_3CF_2CF_2CH_2CH_2CH_2$-, a surface free energy of 16.3 mN/m^2 is found. This much lower surface free energy is of considerable interest in the development of new materials that will have minimal interaction with the environment. Such surfaces are needed for diverse applications such as contact lenses, biomaterials for implants, and water purification systems.

The author presented some of his work on polymer surface chemistry supported by the ONR Scientific Officer Research Program and conducted at the Naval Research Laboratory. Preliminary results were described concerning an investigation of polyurethane-ureas containing unusual diols that promote the formation of *minimally adhesive surfaces*, that are thus unattractive to settling marine organisms. The goal of this work is to prepare model surfaces of precisely defined chemistry and morphology, so that the surface features that act to discourage settlement of marine organisms may be discerned. The initial approach focuses on the design of surfaces with

a. low surface energies, and
b. low glass transition temperatures.

Low surface energies should minimize polar forces (hydrogen bonding, etc.) and nonpolar interactions (lipophilic or hydrocarbon-hydrocarbon). A low glass transition temperature creates a liquid-like surface that is meant to minimize mechanical locking of a prospective adherent.

Toward this end, copolymers were prepared of an aminopropyl end-capped dimethylsiloxane oligomer and isophorone diisocyanate with 1,4-benzenedimethanol as the chain extender (Fig. 2). The synthesis of the polymer was carried out in a manner that controlled hard block and soft block chain lengths. Thermal and mechanical properties of copolymers containing benzene dimethanol as a chain extender were found to be superior to those without chain extender. Contact angle measurements were used to calculate surface energies (about 23 mN/m^2) indistinguishable from pure poly(dimethylsiloxane), $(Me_2SiO)_n$, or "silicone". Angle resolved X-ray photoelectron spectroscopy gives insight into the effects of compositional changes caused by increased chain extender. Low-angle (15°) data give compositional information about the near surface (1 nm), while high angle (75°) interrogates a sample depth of 10-10 nm. The results indicate that the surface is almost pure "silicone" in nature. The near surface silicone region is followed by a region of high concentration of hard blocks derived from the diisocyanate and chain extender, if present. The

thickness of this almost pure silicone region increases with increasing molecular weight of the silicone segment. A "processing" treatment of the films, viz., brief annealing at 125°C causes a thickening in the surface silicone layer over that obtained by solvent casting. These results and related work on a nylon-silicone system are correlated with calculations of root-mean-square end-to-end distances of the silicone segment.

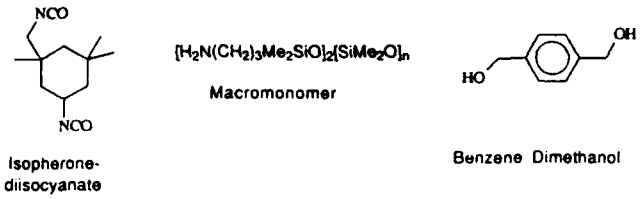

Fig. 2 — Synthesis of polymer to control hard block and soft block chain lengths

In the future, tests of these model surfaces in an estuarian location are planned to correlate basic characterization parameters with the extent and nature of settlement of marine organisms.

POLYMERS FOR OPTICAL AND ELECTRONIC APPLICATIONS

An interesting collaborative research project aimed at making polyvinylidene chloride (PVC) conducting was reported by Professor T. J. Kang, Department of Fiber Science, Seoul National University, Korea; Professor Seizo Miyata, Department of Material Systems Engineering, Tokyo University of Agriculture and Technology, Japan; and Drs. Y. Miyaki and A. Akimoto, Polymers Research Laboratory, Tosoh Corporation, Yokkaichi, Japan. Pyrrole was diffused into the PVC matrix in the presence of a swelling medium such as acetonitrile/methanol. Oxidative polymerization (ferric chloride) of the diffused pyrrole gives high conductivity and good penetration of the oxidant into the PVC matrix. The thickness of the conducting layer was estimated at 0.1μm by a number of techniques, including X-ray photoelectron spectroscopy. With longer diffusion times, the conductivity of the PVC/polypyrrole composite could be brought into the range necessary for electromagnetic interference applications.

Research on the synthesis of liquid crystalline polyacetylene derivatives was described by Professor H. Shirakawa, University of Tsukuba, Japan. This work is a collaborative effort with his coworkers at Tsukuba and Dr. K. Araya, Advanced Research laboratory, Hitachi, Ltd., Saitama, Japan. The idea was to introduce mesogenic units on the polyacetylene backbone. To this end, a number of acetylene monomers were synthesized with mesogenic side-chains. Polymerization of the monomers was effected by using Zeigler-Natta and metathesis polymerization methods. The method of polymerization effected the polymer stereochemistry, which in turn effected the nature of the liquid crystalline phases observed. The significance of this work lies in the combination of liquid crystallinity and the presence of a polymer backbone that has a delocalized electronic state that is a prerequisite for electronic conductivity.

Professor Alan Heeger, UC Santa Barbara, reported on visible light emission from Schottky diodes made from semiconducting polymers. His results demonstrated that light emitting diodes (LED's) can be fabricated by casting the polymer film from solution with no subsequent processing or heat treatment. Electrical characterization reveals diode behavior with rectification rations of 100,000. Electroluminescence quantum efficiencies (photons out per electron is in) of 1% have been achieved. The discovery of conducting polymer LEDs expands the possible applications for conducting polymers into the area of active light sources. By using different polymers and by modification of polymer structure, LEDs have demonstrated various colors (red, yellow, green, an blue) with impressive efficiency, brightness, and uniformity. Pulsed excitation provides important information. The transient on/off response will ultimately limit the high-frequency modulation of such light sources, and the linearity of light intensity vs current to high injection levels will determine the potential of polymer LEDs in applications that require multiplexing (e.g., displays) or which require high levels of pumping (e.g., diode lasers). Transient electroluminescence from polymer LEDs have now been carried out. Resistance circuit limited response is observed with rise and fall times below 50 ns. With low-duty cycle pulses (0.5$) the electroluminescence intensity remains proportional to the current at values greater than possible with dc operation. A significant problem to be solved is the electrode material. Currently, high efficiency polymer LEDs require a high-work function cathode such as calcium. The latter is inconvenient to use and is highly reactive to air.

Professor A. G. MacDiarmid reviewed the science and technology of polyaniline, a readily

synthesized, stable, processable polymer with high electrical conductivity. He noted that the concept of "doping" is the unifying theme that distinguishes "electronically conducting polymers" from all others. Doping, or more properly partial oxidation, results in dramatic electronic and magnetic changes with a concomitant increase in conductivity to or approaching the metallic regime, depending on the type of polymer. Doping phenomena and the chief types of dopable organic polymers were described with emphasis on polyaniline, which recently has become commercially available on a relatively large scale and is the leading conducting polymer for technological applications. Polyaniline, the emeraldine salt form that is shown in Fig. 3, has considerable promise for electromagnetic interference (EMI) shielding and is already used in commercial rechargeable batteries. A leading potential technological application uses polyaniline films as membranes for gas separations.

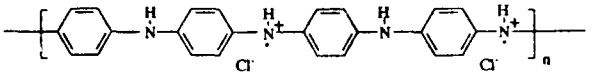

Fig. 3 — The "emeraldine chloride" form of polyaniline

The possibility that the polyaniline family of polymers may exhibit properties that allow for the storage of optical information was presented by Professor A. Epstein, Ohio State University. Photoexcitation of several forms of polyaniline results in long-lived changes in the absorption spectra, associated with trapped charged defect states. These new absorptions exhibit long lifetimes at low temperatures, i.e., below 250K, with erasure occurring upon warming the sample. The use of polyaniline or its derivatives for optical information storage would involve writing information on a thin film, composite or blend of polyaniline with a visible or UV laser beam, and subsequently, reading the information with a diode laser and an appropriate detector tuned near the peak in the photoinduced absorption spectrum (1.4-1.5 eV). Studies in progress include a survey of additional materials that exhibit similar long-lived optical effects but with a more convenient temperature range for accessing a read/write cycle.

Professor T. Shimidzu, Kyoto University, presented work on functionalization of conducting polymers for advanced materials applications. One objective of their work is to control the electric, optical, and other properties specific to the depth of structure by spatially modulating the composition of the polymer in a thin film. Expressed in different terms, the goal of this work was the fabrication of an organic superlatice comprised of conjugated polymer layers. To achieve this objective, a programmed potential was used in electropolymerization. The depth profiles of the heterolayers, thickness, and polymer composition are controlled by applied electrode potential, and a nanometer order layered structure was synthesized. Quantum size effects were demonstrated in these films.

SUMMARY

Overall, ICFPAM accomplished its goals of showcasing some of the most interesting work in advanced polymer chemistry, physics, materials science, and engineering. The Indonesian scientists enjoyed the great opportunity to present their own research and to learn firsthand of efforts going on internationally. This meeting will help in continuing the momentum in Indonesia to establish an educational infrastructure and expanded research activities in polymer science. The efforts of the meeting organizers were appreciated at the highest level of government, as demonstrated by the participation of President Soeharto.

Dr. Kenneth J. Wynne, who earned his Ph.D. from the University of Massachusetts in 1965, is Program Manager, Organic and Polymeric Materials at the Office of Naval Research, Arlington, VA 22217-5660. Dr. Wynne's research interests include polymer surface design and characterization, electronically conducting polymers, polymers for optical applications, and inorganic polymers. He is active in the Polymer Division of the American Chemical Society. He is a member of the Editorial Advisory Boards of the Journal of Applied Polymer Science, the Journal of Inorganic and Organometallic Polymers, and Polymers for Advanced Technologies.

ADVANCES IN COMPOSITES MATERIALS AND TECHNOLOGY

Highlights of the International Conference on "Advanced Composites '93" (15-19 Feb 1993) and Forum on "Composite Materials and Technology" (22-23 Feb 1993) held respectively at Wollongong and Sydney, Australia, are summarized.

Iqbal Ahmad

INTRODUCTION

In the southern hemisphere, this was the first international conference on advanced composites. Two hundred forty scientists from 26 countries presented 125 papers in three parallel sessions. In addition to the plenary lecture, two keynote lectures were presented every day. Their titles are as follows:

Plenary:
Dr. Joseph K. Lees, Director South East Asian Marketing, DuPont: "Keeping the Dream Going"

Keynote:
Klaus Friedrich, Institute for Composite Materials, Univ. Kaiserlautern: "Tribology of Polymer Composites"

R. J. Arsenault, Dept. of Materials, Univ. Maryland, MD.: "Strengthening and Deformation Mechanisms of Discontinuous Metal Matrix Composites"

Ashok Dhingra, DuPont Fiber and Composite Development Center, Willmington: "Future Trends in Advanced Fibers and Composite Materials".

K. Higashi, College of Engineering, University of Osaka: "Recent Work on Superplastic Composites"

A. Di. Hio, Dipartimento di Energia, Universita L'Aquila, Italy: "Machining of Composite Materials"

A. A. Baker, DSTO Aeronautical Research Lab, Melbourne: "Application of Boron/Epoxy composites in the Repair of the Metallic Aircraft Components"

M. R. Piggott, University of Toronto, Toronto, Ontario: "Compressive Strength of Composites- How to Measure and Improve it"

C. G. Krishnadas, Hindustan Aeronautics Ltd., Banglore, India: "Development of Metalloceramic Friction Materials for Aircraft Brakes"

Yiu-Wing Mai, Dept. Mechanical Engineering Univ. of Sydney, Sydney, Australia: "Optimization of Toughness and Strength of Fiber Composites with Controlled Interfaces"

A. E. Bogdanovich, Latvian Academy of Sciences, Riga, Latvia: "Three Dimensional Analysis of Laminated Composite Plates"

Contributed papers were presented at the following sessions:

Polymer Matrix Composites
Ceramic Matrix Composites
Fabrication and Processing
Creep and Time Dependent Behavior
Fatigue and Fracture
Interfaces in Composites
Damage and Damage Analysis

Wear, Joining and Adhesion
Applications
Emerging Technologies and Applications
Hybrid Composites and Properties
Analysis and Design of Composite Structures
Modeling

HIGHLIGHTS

In the following, some highlights of the conference are summarized based on the limited number of papers that I could audit and from the abstracts and personal discussions, in particular those relating to the work reported by the participants from Australia.

The conference was officially opened by the Australian Minister of Science and Technology, Mr. Ross Free. He welcomed the attendees and stated that New South Wales had the largest concentration of activities in the field of composite materials in Australia. He cited the production facilities of composites at the Hawker de Haviland, which supports McDonald Douglas, Boeing, and the Australian aircraft industry, the Australian Center of Aerospace Science and Technology and Cooperative Research Centers (CRC) under which ten centers of excellence in research were planned to be established by 1994. In addition there were research activities in composite science and technology in the academic institutions, such as that at the University of Sydney and at the CSIRO, Sydney. He considered this conference as very important for the New South Wales future trade and industry.

Composite technology has progressed during the last thirty years, driven essentially by the demand of the defense, aircraft, and space programs in the United States and other countries. However, it has not been able to be established as a large scale industry, because of a number of problems such as high cost of raw materials, high cost of component fabrication and relatively low reliability. These lead to only a restricted demand, and therefore, a limited market activity. With recent downsizing of the defense budget, R&D activities in the field of composite materials and their processing are expected to be reduced. Also, although the aircraft industry continues to increase the use of composite materials in the new generation of the aircraft, some backlash is being echoed from the airlines regarding the performance and cost of maintenance of the composite components. This has resulted in the growing number of companies and universities either exiting or reducing the level of their operations in this area. In fact, corporations like BASF, ICI, Phillips, Hercules, Amoco, BP, and Alcoa have either stopped their operations or reduced them. DuPont has discontinued producing the FP fibers altogether.

Dwelling on this gloomy picture, Dr. Lees, Director of the DuPont's South Seast Asian Activities, the plenary speaker of the conference, whom I had the pleasure of introducing, explained that this was a temporary phase. He stated that in the scenario of global developments in the manufacturing and marketing, it was necessary to develop a trained cadre of engineers who could integrate design, manufacturing and material selection with the objective of optimizing the performance at a reduced cost. He also suggested partnership between companies to allow effective synergism of technological capabilities, since it is not possible for a single company to afford to develop all the knowledge and technology needed for the successful manufacture of composite structures. Giving the example of DuPont, he stated that by teaming up with ICI/Fibrite on prepreg processing, DuPont was able to introduce Avimid K, quite rapidly, with significant reduction in the development cost. Similarly, collaborating with Hexel, DuPont introduced Korex. Under the Federal sponsorship, DuPont is combining their knowledge of thermoplastic filament winding with Hercules' knowledge of thermoset fiber placement. Dr. Lees suggested that the reduction of the DoD support funds for the composite technology, may prove to be an advantage as it would force the U.S. developers to stop depending on a single market (defense) and focus on the commercial market. Apparently the trend has started. Alternate manufacturing processes involving both thermoset and thermoplastic systems are in the late stage of development. Simulearning concepts are being applied, and rapid development in parallel programming and neural network technology will continue to feed this development. Dr. Ashok Dhingra also from DuPont, in his keynote paper, predicted that the future developments in this field would not only make possible to design and fabricate composites at low cost, but also through computer integrated manufacturing concepts it would be possible to cater to customers with specific requirements from the same plant, without depending on large volume production to achieve low cost. He stated that while the industrial revolution of the nineteenth century was unique because it brought in the mass production as a means of bringing the cost of production down, the new revolution would be in

approaches to develop specific solutions and transition of using isotropic materials to anisotropic materials. Furthermore, the new multifunctional materials, leading to 'smart' materials and systems will be developed. These systems, exemplified by the polymer composites with embedded optical fibers and wires of shape memory alloys, or those containing piezoelectric coatings are already being developed VPI, Mcdonald Douglas and many other laboratories, both under the federal and industrial funding.

One of the distinctive contributions in Australia, in the area of composites, is by the DSTO Aeronautical Research Laboratory, Melbourne, where boron/epoxy composites have been successfully applied to repair metallic aircraft components. Dr. Alan Baker of this lab, in his keynote lecture described a number of applications of this technology that included repair of fatigue and stress corrosion cracks, restoration of stiffness and strength lost by general corrosion and strain reduction in critical regions. A boron fiber-epoxy repair of the corrosion damage in the keel beam of a Boeing 767 aircraft recently gained certification in Australia and the United States. An ongoing demonstrator program involves the application of this repair technique to RAAF F111 and some civil aircraft, which is expected to provide certification from relevant air worthiness authorities.

Other keynote speeches consisted essentially of reviews of state of the art without much exciting news. Professor Arsenault discussed his previously proposed mechanism of strengthening metal matrix composites containing discontinuous reinforcements, according to which the improvement of strength was due to the work hardening of the matrix resulting from the difference in the thermal expansion coefficients of the reinforcement and the matrix. Finite element analysis of such composite systems indicated that the deformation in the matrix was more severe where there were clusters of the reinforcement. Klaus Friedrich, after describing the fundamental relationships of wear and friction, reported results of sliding wear experiments with continuous glass, carbon and aramide fiber reinforced polymer composites against steel surfaces. Techniques for the cutting and machining of glass fiber reinforced plastics and aramide fiber reinforced plastics were reviewed by Dr. Tagliaferi of Instituto Ingegneria Meccanica, Solermo University, in which he highlighted the importance of the fiber volume percentage on the machinability of these composites.

Professor Mai, Sydney University, reported that application of thin layer of a thermoplastic coating such as that of polyvinyl alcohol on the fibers in the carbon fiber/epoxy and Kevlar fiber/epoxy composites improved their fracture toughness by as much as one-hundred percent, thus indicating the importance of the control of interfaces in these systems. In another presentation, jointly authored with Dr. C. Baillie, results of single fiber pullout tests on carbon fiber/epoxy system were reported. It was shown that the maximum pullout length Lmax was comparable to the mean fragment length measured by the fragmentation test for each fiber tested. These pullout tests were performed to measure properties of the interface between treated carbon fiber and epoxy resin.

To give an idea of the overall magnitude of the research activity in composites in Australia, the host country of the conference and the titles of the papers presented by the Australian researchers are reproduced below:

Universities

"The Effect of Particulate Distribution on the Grain Size Distribution in the 2014Al/Al2O3 PMMC," M. Ferry et al., University of Wollongong, Wolongong, NSW

"Potable Holographic Interferometry Testing System: Application to Crack Patching Quality Control," R. B. Heslehurst et al., University of New South Wales, Australian Defense Academy, Canberra

"Deformation Behavior of SiC Particulate Reinforced 7075Al Alloy at High Temperature," A. Razaghian et al., University of Wollongong, Wollongong, NSW

"Status of and the Prospects for the Development of Titanium Metal Matrix Composites," P.K. Dutta et al., Dept. of Metallurgy, University of South Australia

"Tensile and Impact Behavior of Natural Fiber Reinforced Composite Materials," Victoria University of Technology, Melbourne

"Flexure and Impact Properties of Sandwich Panels Used in Surfboard Construction," J.A. Manning et al., University of New South Wales, Kensington, NSW

"Effect of Chemical Treatment of Chemical Fibers on Their Adhesion Performance with Polyester Resin,"

M. G. Stevensons et al., University of Technology Sydney, NSW

"Effect of Temperature and Strain Rate on Flow Behavior and Microstructure in 6061 Aluminum Containing Aluminum Oxide particles," D. Yu and T. Chandra, University of Wollongong, NSW

"Electromagnetic Enhancement of Wetting in the Al-Al2O3 and Al-Graphite Systems," P.J.Bunyan and S.H. Huo, University of Melbourne, Parkville, Victoria

"Epoxy Resin Toughened with Hydroxy-terminated Bisphenol-A Polysulphones," B. G. Min et al., Monash University, Clayton, Victoria

"Mechanical Properties of Superconducting Ceramic/Polymer Composites,' J. Du-Moore et al, University of Technology, Sydney

"On Stitching as a Method For Improving the Delamination Resistance of CFRPs," Kimberley Dransfield et al, University of Sydney, NSW

"Individual Effects of Linear Polymerization and Crosslinking Reactions on the Development of Glass Transition Temperature of a Thermoset Polymer," R.G. Min et al, Monash University, Clayton, Victoria

"Influence of Heat Treatment on Mechanical and Fracture Properties of an Alumina Microsphere Reinforced Aluminum Matrix Composite," University of Sydney, NSW

"Fatigue Crack Propagation in a Particulate Reinforced Metal Matrix Composites at Room and Elevated Temperature," University of Sydney, NSW

"Deformation Behavior of Carbon Fiber Reinforced PEEK," P. Y. B. Yar, Australian National University, Canberra

"Thermochemically Bonded Ceramic Matrix Composite Coatings," M. Samandi and L. F. Ashbolt, University of Wollongong, Wollongong, NSW

"Ambient and Elevated Temperatures Determined by Short Rod Technique," Greg Heness and Yiu-Weing Mai, University of Sydney, Sydney, NSW

"Fracture Toughness of Some Particulate Reinforced 6061 Al Alloy Composite and Wear Mechanisms of Epoxy Resins," G. M. Spinks et al, University of Wollongong, Wollongong, NSW

"Buckling and Post Buckling Behavior of Thin Skinned Reinforced Stiffened Panels," Brian G. Falzon, Aeronautical Engineering Department, University of Sydney

"Design of Hybrid Composite Roof Bar," Paul J. Falzon, Dept. Aerospace Engg, Royal Melbourne Inst. Technology, Melbourne, Victoria

Government

"Laboratory Scale Unidirectional Tape Prepregger," R. S. P. Coutts, CSIRO, Clayton, Victoria

"Tungsten Fracture and Shear Properties of Relevance to Tungsten Alloy Penetrator Performance," R. L. Woodward, DSTO Materials Research Lab, Ascot Vale, Victoria

"New Epoxy Systems for Aerospace Composites," R. Eibel et al., CSIRO, Clayton, Victoria

"Effect of Hot/wet Environments on the Fatigue Behavior of Composite-to-Metal Mechanically Fastened Joints," S.C. Gales and D.S. Saunders, DSTO, Materials Research Laboratory, Ascot Vale, Victoria

"New High Temperature Matrix Resin System for Use In Advanced Composites," R. Eibel et al., CSIRO, Clayton, Victoria

"Interfacial Reactions in COMRAL-85Metal Matrix Composites," John Drennan et al, CSIRO, Clayton, Victoria

Private Industries

"The Settling of Reinforcement Particles During the Casting of Aluminum-Silicon Base Alloys," N. Stategew et al, Comalco Research Laboratories, Thomastown, Victoria

"Prediction of Residual Strength of Impact Damaged Aerospace Composite Structures," Amar Garg, Aerospace Technology of Australia Pty Ltd,Port Melbourne, Melbourne, Victoria

"Repair of Composite Structures," Amar Garg et al., Aerospace technology Pty, Port Melbourne, Victoria

The above list of the papers indicate a strong activity in the area of polymer and metal matrix composites, but very little in the CMCs.

Recent work on the superplastic composites was the topic of the keynote lecture by Professor K. Higashi of the University of Osaka, who was introduced by Professor Oleg Sherby of Stanford University as the world leader in this field. He reviewed the work of Nieh et al., (Lockheed) and others on the superplastic behavior of aluminum alloys reinforced with silicon carbide/silicon nitride whiskers or particles in which, in some systems, an elongation, as much as 620%, was reported at strain rates as high as 1/s. He reported elongations as high as 1000% in mechanically alloyed 9021Al deformed at strain rates from 10-100/s. The maximum elongation obtained in his laboratory was 1250% at 50/s and 823°K, highest ever reported for such composite systems. Oleg Sherby described his own recent work on the fabrication of ultrahigh carbon steel-
aluminum bronze laminated composite by solid-state bonding at relatively low temperature of 670-700°C. An elongation of 650% was observed at 750°C with no visible crack in the bronze layer. It was shown that a strain rate sensitivity exponent of 0.5 could be obtained in this system at a temperature of 750-850°C and low-strain rates. He compared the deformation characteristics of this system with that of UHCS/brass, which cracks readily at elevated temperatures. He explained the superior behavior of the UHCS/bronze system to be due to the fine grain size of the bronze as well that of the UCHS laminates.

Considering the tungsten alloys used in the penetrators as composites of tungsten phase in the W-Ni-Fe matrix, Woodward of the Materials Research Laboratory of DSTO, suggested that the rupture of these composites during the penetration was not due to the nucleation and growth mechanism, but by localized shearing at the tip of the projectile, progressively removing small amounts of material without introducing damage to the body of the projectile. His studies show that in this process no adiabatic shear was involved. Animesh Bose, in a paper coauthored with Dowding of MTL, reviewed the developments in the fabrication of high-density tungsten alloys used for penetrators, and reported that addition of refractory metals such as rhenium and molybdenum improved the fracture toughness and impact behavior of these alloys. Sheldon Cytron described the result of some of the work at the ARDEC, in which the high-density alloys were being fabricated from rapidly solidified powders by solid state sintering and explosive compaction.

Although use of composites in the aerospace structures is increasing because of their low density and improved mechanical properties, these structures, however, are prone to damage on impact. Dr. Amar Garg of Aerospace Technologies, using a three parametric approaches, proposed a model to predict the residual strength of impact damaged structures. Experimental data agreed favorably with the predicted behavior. Nevin Rupert of the Ballistic Research Lab, Aberdeen Proving Ground, described the process for the fabrication of a composite of depleted uranium containing uranium oxide, and compared its ballistic behavior with baseline aluminum oxide. For details, the readers are encouraged to contact Dr. Rupert directly.

An interesting paper was given by Atsushi Shirai of the Tokyo Kasei Gakuin University, Machida, Tokyo. In this paper he described 'ferrocement', which is a composite of cement mortar reinforced with closely spaced layers of continuous and relatively small diameter wire meshes. It has been used in housing units, water tanks, and boats because of its excellent toughness and impact resistance. However,industry needs a product that is corrosion resistant and has higher specific mechanical properties. To satisfy these requirements, ferrocement is being modified by the addition of polymers and fibers. Steel fiber reinforced polymer modified mortar (SFRPCM) and carbon fiber reinforced cement (CFRC) as matrices have been evaluated and have been found to be superior to the conventional ferrocement.

THE FORUM

In a Forum held in Sydney after the conference, invited participants discussed issues of marketing, technology transfer, standardization, and cost. It was the general consensus that the user community is not looking for any new composite systems. What was needed was radical approaches to bringing the cost of the fabricated components to a point where

they are competitive with metals. It was also pointed out that the competition from the metals is getting tougher as the metal industry is improving the alloys as well as the fabrication technology that along with a long history of their successful use and the designer and user confidence would be even more difficult to beat. Therefore, the use of composite materials will grow mainly in specialized areas such as the aerospace, sports, and limited construction niches. Professor Ma, representing Taiwan, stated that in Taiwan there were 4500 small and large manufacturing companies that employ approximately 16,000 workers to produce sport and many other consumer items. In fact, some of this technology is being transferred to countries like Thailand, where the labor cost is still low. Recent study, supported by ARO and other agencies, of the Japanese approach to low-cost polymer composite manufacturing processes, also indicate the cost of production of materials and component fabrication is a challenge that must be faced. It would be necessary to establish collaborative programs to meet this challenge. As was suggested by Dr. Lee of DuPont, the industry has to start sharing technical know-hows and databases to meet this challenge and to achieve reduced process development costs, which no single commercial outfit can afford, these days.

Dr. Iqbal Ahmad is the director of the Army Research Office (ARO) Far East. He has a Ph.D. degree in physical chemistry from Imperial College, London and is a Fellow of the Royal Society of Chemistry, London. Prior to his present position, Dr. Ahmad was a program manager in the area of materials science at ARO, Research Triangle Park, North Carolina.

COLD-FUSION RESEARCH IN JAPAN: AN UPDATE

Six months after the Third International Conference on Cold Fusion, the view from Japan is more clouded than before. Attempts to demonstrate experimentally the nuclear origin of the observed excess heat continue to be frustratingly non-reproducible. This update reports on the current state of research of three major cold-fusion research groups in Japan. Each of the three have experienced poor reproducibility of experiment during the past months. In my judgement, careful and thorough materials characterization seems to be greatly needed at this time. The time for skepticism has not passed, but the time for relegating spontaneous solid-state nuclear phenomena to the realm of pathological science has not yet arrived either.

Victor Rehn

INTRODUCTION

To monitor research progress in the search for spontaneous solid-state nuclear phenomena ("cold fusion",) we have recently visited the laboratories of Dr. Eiichi Yamaguchi [1], NTT Basic Research Laboratories; Dr. Shinji Nezu [2], IMRA Material R&D Co; and Prof. Akito Takahashi [3], Osaka University. This is an update to the cold-fusion assessment that we released last November, following the Third International Conference on Cold Fusion (ICCF#3).4. As the situation changes, we plan to update our assessment of this highly controversial field of research.

NTT

In the report of last November, we strongly weighted the reports by Yamaguchi as representing the most promising and straight-forward experimental arrangements used to date in this field of research. Yamaguchi uses a high-vacuum environment in which to search for the possible products of solid-state nuclear reactions in a much cleaner environment than the electrolytic solution.

In the Yamaguchi experiment, Pd plates are loaded with deuterium (^{2}H, or D), hydrogen, or a mixture of both, via exposure to the gas at room temperature and absolute pressure of 400 T. The dissolved gas is sealed into the ▲ d by using evaporated films: 200 nm of Au on the bottom surface of the plate, and 20 nm of MnO or other oxide on the top surface. This asymmetry generates a temperature gradient that is thought to be of importance in increasing the concentration of deuterium in the near-surface region.

The emission of charged particles [protons, tritons ($^3H^+$ or T^+) or alpha particles ($^4He^{++}$), etc.,] gases (^{4}He, ^{3}He, HT, etc.) and neutrons are measured while the temperature and the strain in the two Pd plates are monitored. Electrical bias, opposite polarity in the two adjacent plates, has been used to determine whether electromigration of D^+ or H^+ ions within the Pd is involved.

Upon visiting NTT, we learned the following:

1. NTT has quadrupled the level of effort from one full-time researcher (Yamaguchi) to four. We are told that the funding is entirely internal NTT research money. Note that NTT is part of MITI's hydrogen-energy consortium, however, which encourages exploration of cold fusion as a possible future energy source.

2. In addition to the all metal high-vacuum experimental apparatus used by Yamaguchi, at

least one new similar chamber is being readied. The absence of a background of ^{4}He or mass-3 molecules to contend with, as well as the observation of time correlation among heat production, ^{4}He production, and charged-particle production are important factors in the evaluation of the Yamaguchi results.

3. Following the series of the five consecutive successful runs of August 1992, all of which showed evidence of nuclear activity, Yamaguchi fell victim to the nonreproducibility virus that has infected so many workers in this field. Subsequent attempts to precisely or approximately repeat the same experiments failed to show evidence of nuclear activity. Yamaguchi continues to stand behind his previous results. We found that his experimental apparatus was set up as reported, and that he had performed various calibration and performance tests appropriately. Currently, his attempts to understand the failure to reproduce previous results center around materials and process questions more than equipment considerations.

4. Although the mass spectrometric evidence of ^{4}He production remains unquestioned by Yamaguchi, the ability of his Extrel instrument to distinguish between the molecular deuterium and the hydrogen-tritium molecule is now questioned. He has observed drifts in the Extrel output of the order of 0.1%, which is just the mass difference of the two molecular isotopes. The 0.6% mass differential between ^{4}He and molecular deuterium lies outside the drift range. Hence, the observation of ^{4}He production still appears to be a firm experimental fact. If ^{4}He is produced in the system, it could only be through some sort of nuclear reaction. The amount of ^{4}He produced is quite large for explaining through some impurity or minor constituent phenomena.

The Extrel company, now under new ownership, has been unable to eliminate the drift problem, and Yamaguchi has ordered a new instrument made in Japan, which claims an order of magnitude better long-term stability. (Takahashi has recently received one of these Japanese high-stability, high-resolution mass spectrometers. See below.)

During the chaotic, explosive releases of gas (and heat) from the NTT samples, the ratio partial pressures of molecules of nominal mass 3 to that of molecules of nominal mass either 2 or 4 increases dramatically, as detected by two Spectramass Selector quadrupole mass spectrometers in the gas-sampling chamber.

However, the identification of gaseous mass-3 species by high-resolution mass-spectrometric measurement in the mass-3 range had not yet been started because of the stability problems with the Extrel mass spectrometer. In this mass range, it will be necessary to distinguish the mass difference between ^{3}He, the tritium atom, the HD molecule, and the HHH molecule. Relative to ^{3}He, these differentials are 0.00066%, 0.192%, and 0.247%, respectively. Distinguishing ^{3}He from T is very demanding, but the HD and HHH molecules present less of a problem.

J. Schwinger [5] suggested in 1990 that

$$p + d \rightarrow {}^3He$$

should be more probable than

$$d + d \rightarrow {}^4He, \text{ or}$$

$$d + d \rightarrow {}^3He + n.$$

From this viewpoint, ^{3}He and ^{4}He would be the important nuclear products to detect unambiguously. Tritium has been shown to be negligible in the hydrogen or deuterium supplies used by NTT, and in the Pd and other materials as well.

5. Neutrons have been observed by Yamaguchi only once, and have not been reproduced. Yamaguchi is not concentrating on the observation of neutrons, and recently has not operated the neutron detector. The rate of 2,000,000 neutrons per second that has been reported previously, accounted for both the detector efficiency and the geometry factor. Thus, that once-recorded neutron-emission rate represents only a tiny fraction of the nuclear activity needed to account for the excess power of 0.5-2 W, as observed by Yamaguchi.

6. During the August 1992 runs, there was a disconcerting observation of "excess" heat generation in Pd plates loaded with pure hydrogen. No ^{4}He evolution was detected from the Pd:H samples, but an increase in the partial pressure of mass-3 gas was detected to accompany, time-correlated, the chaotic temperature rises. No explanation was offered, nor there is any explanation apparent for these observations using Pd:H samples. Such unexplained observations obtained with the same experimental system and the same sample preparation method shake my confidence in the results on Pd:D. The disappearance of the reproducibility of August 1992, adds to my skepticism. Clearly, more consistent results are required before spontaneous solid-state nuclear reactions can be considered as demonstrated or demonstrable scientific phenomena.

IMRA

Next we visited the laboratory of Dr. Shinji Nezu, IMRA Material R&D Co. [2]. IMRA is a one-year-old subsidiary of Aisen Auto Parts Co., which in turn is a subsidiary of Toyota Motors. IMRA is named for the recently deceased Minoru Toyoda, brother of the founder of Toyota Motors (IMRA: Institute Minoru Resherché Advancé). Also, there are two related companies: IMRA Europe and IMRA America. All are coordinated with Toyota through Aisen.

We were hosted by the IMRA-Japan President, Masami Ishii; the manager of the cold-fusion research, Tamio Ohi; and Dr. Nezu, the chief investigator. IMRA Japan has three main research areas: cold-fusion research (about 11 persons), yttrium-barium-copper oxide superconductor research, and hydrogen-storage research. The cold-fusion research seems to be mainly oriented toward development of Pd materials. They also have three cold-fusion reactors of the Fleischmann-Pons type in operation. They are beginning research for cold fusion in single-crystal sodium-tungstate bronze after Vladimer Tsarev at ICCF#3 gave a report summarizing Russia's cold-fusion research.

IMRA's main effort has been the study of deuterium loading of Pd as a function of metallurgical and chemical preparation. However, they are not publishing these results at this time. They are very interested in TEM and SEM studies of their Pd after various sequences of deuterium loading. They reported observing macroscopic cracking of the material at high loadings, after which heat-generation is said to diminish. They stated that deuterium loading within crystallites is about 0.6 D/Pd, considered by consensus to be inadequate for cold fusion to occur. Hence cold-fusion in single-crystal Pd would be unlikely.

In general, Dr. Nezu seemed less than enthusiastic about Pons-Fleischmann-type cold fusion, but quite curious about the possibilities for cold fusion in the sodium-tungstate bronze system.

OSAKA UNIVERSITY

Finally, we visited Prof. Akito Takahashi, Osaka University [3]. Professor Takahashi is well known in the United States since his visits to MIT and Texas A&M a year ago. His group, which included about 15 students, two Assistant Professors, and one technician, is split between cold- and hot-fusion research. To date, however, no Ph.D. theses have been assigned in cold-fusion research. The laboratory includes the Oktavian 14 MeV accelerator, which is used for both types of fusion research.

Professor Takahashi has a variety of cold-fusion research activities underway—one of the most aggressive cold-fusion-research programs in Japan. At ICCF#3, he presented three poster papers in addition to his invited presentation and his participation in a round-table discussion. In the past, he developed cyclic-current control for Pd:D electrolysis experiments, from which he obtained significantly improved reproducibility, as reported during his U.S.A. tour, and at ICCF#3.

One of his ICCF#3 papers reported the output heat of 410 MJ compared with the input heat of 250 MJ. This was an average of 32 W excess heat for a two-month period. Takahashi estimated the probable error in his excess heat power measurement to be plus or minus 1 W that he attributed mostly to turbulence in the electrolyte flow. The peak rate of the chaotic production of excess heat was 130 W, more than four times the average rate. In his electrolytic cell, he used an electrolyte of deuterated lithium hydroxide, LiOD, dissolved in heavy water. The cell was operated in the high-low cyclic-current mode with square-wave current waveform, typically 0.3A to 4.5A and a 12-hr period. This experiment is continuing, but the results are not as those previously obtained.

In a new experiment, Takahashi uses an all stainless steel, closed electrolysis cell, and has added high-resolution mass spectroscopy of the effluent gases. This experiment is now underway, but no results are yet available. This will provide him with measurements of ^{4}He and ^{3}He generation for comparison with Yamaguchi's results, and for use in understanding the mechanism of spontaneous solid-state nuclear phenomena.

Takahashi is using two other experimental procedures as well. By using a 240 KeV beam of deuterons, Takahashi has implanted Pd and Ti foils, and has measured radioactive emissions during and following implantation. These results were reported at the Nagoya Conference. There are no new results available at this time. Additionally, Takahashi is preparing a gas-phase experiment aimed at detecting high-energy charged particles, neutrons, and tritium as simultaneously as possible. He hopes to show consistency among these four experimental methods, and then to demonstrate theoretical and experimental evidence of the mechanism of spontaneous solid-state nuclear phenomena.

Takahashi has proposed mechanisms for multibody fusion of three or four deuterons in Pd. Located on octahedral sites between Pd atoms, four deuterons simultaneously penetrate the mutual Coulomb barrier separating them with dynamical (phonon) assistance. The product nucleus is formed in the (empty) tetrahedral site at the center of the tetrahedron formed by the four octahedral sites. The barrier penetration is made possible by the fluctuational compression of the "gas" of 44 local electrons; 40 from four nearest Pd atoms, and 4 from the deuterium atoms. For the case of four-deuterium fusion, the product proposed would be two ^{4}He atoms plus 47.6 MeV of kinetic energy. Similar schemes were proposed for three deuterium atoms, or mixtures of deuterium and hydrogen.

Takahashi reported some experimental support for these mechanisms in his deuteron-implantation results presented at ICCF#3. Recently Dr. Vladimir Tsarev, Lebedev Institute, Moscow, has collaborated with Takahashi in the calculations of multibody fusion mechanisms. Their results could be ready for publication soon.

However, by April 1993, Takahashi, also, had fallen victim of the non-reproducibility virus! After observing fair reproducibility between two sets of experiments conducted in 1992, Takahashi's recent results are discouraging at this time. His major goal is experimental reproducibility. If he can show reproducibility, then he seeks to determine the mechanisms. As he fully appreciates, demonstrable reproducibility of experiment is the fundamental necessity. Following that demonstration, perhaps the new field of solid-state nuclear physics may be born. Until then, scientists will retain their healthy balance of curiosity and skepticism.

CONCLUSION

Takahashi's goal is surely the goal of every researcher in this field—reproducibility of experimental results. However illusive, until that goal is attained, cold fusion continues to be little more than a dream. As long as researchers in cold fusion cannot demonstrate reproducible and consistent results, the world must maintain a cautious skepticism to balance the hopeful curiosity about possible new and important physical phenomena.

It would be easy to discount the scattered reports of astonishing spontaneous solid-state nuclear phenomena. Rumors abound of prominent high-energy physicists relegating cold-fusion research results to the category of N-rays and polywater. Sometime in the future this view may be proved accurate, but that proof cannot be given by tabulation of reported yes or no observations, as in an opinion poll. Nature is much more intricate than that.

Our observations are that the Japanese scientists working in the field are competent and conscientious, well equipped and as perplexed by the contradictions in the field as anyone else. They are fully aware that the current level of research here cannot continue for long without a breakthrough in reproducibility.

It seems clear to me that the characterization of materials used, especially the Pd, has not been adequately pursued to date. I am surprised that a more systematic materials-science approach to the study of Pd:D and other promising systems for possible spontaneous solid-state nuclear phenomena has not yet been pursued. Using 99.9% Pd cold-rolled metal plates is far from state-of-the-art materials science. Surface and interface questions remain to be answered. Marvelous analytic, microscopic, and surface-science tools such as STM, TEM and others, have not yet been applied extensively or systematically in this field.

Perhaps cold fusioneers might take a cue from baseball and play the percentages: swing for a base

hit or a squeeze bunt, and save their home-run swing until their batting average improves.

References

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Dr. Victor Rehn is currently a liaison scientist with the Office of Naval Research Asian Office in Tokyo. He assumed this position in May 1991. Since 1965 Dr. Rehn has been a research physicist with the Naval Weapons Center, China Lake, California. He started there as a research physicist in the Semiconductor Physics Branch, then as a supervisory research physicist he headed the Electron Structure of Solids Branch and the Semiconductor and Surface Science Branch, both in the Physics Division, Research Department. Dr Rehn received his B.A. in physics at the University of California, Berkeley in 1953 and his Ph.D. in physics from the University of Pittsburgh in 1962. After completing his thesis research in nuclear quadrupole resonance studies of paradichlorobenzene and related materials, Dr. Rehn studied magneto-acoustics attenuation in metals at the University of Chicago. Upon moving to China Lake, he undertook research in electroreflectance of widegap semiconductors and insulators. Beginning in 1973, he participated in the establishment of the Stanford Synchrotron Radiation Laboratory and continued with the application of synchrotron radiation in research in semiconductors and semiconductor surfaces. In 1976 he initiated a research program in liquid-phase epitaxy, followed in 1984 by research in molecular-beam epitaxial growth and characterization of semiconductor materials and heterostructures. In 1987 he initiated research in the production of yttrium barium copper oxide superconductive thin films using excimer-laser ablation.

9th ANNUAL KEIO UNIVERSITY (JAPAN) SYMPOSIUM ON PARALLEL PROCESSING FOR SCIENTIFIC COMPUTING, 2 MARCH 1993

The 9th Annual Keio University Symposium on Parallel Processing for Scientific Computing, held 2 March 1993 outside Yokohama, is summarized.

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This report is summarized by

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"At-to iu ma ni kyuu-kai me ni nari mashita" "How time flies ! It's hard to believe that we're holding the 9th Annual Keio University Symposium on Parallel Processing for Scientific Computing," began Nodera in his typical low-key style in the opening remarks. Originally this symposium began as a pet project of Professors Nodera and Natori and was financed solely out of their own pockets. Recently, sporadic private and corporate contributions have been made by fans and admirers. And, starting last year (1992), excellent sources of funding have allowed organizers to invite young, active researchers from abroad to participate in this one-day affair. This year, 1993, the audience was happy to welcome two young scientists, Kang. C. Jea and Steven F. Ashby to present their work. Next year Nodera would like to hold a longer, 2-3 day international conference with 5-6 foreign speakers. However, the recession may force him to postpone bigger plans until 1995. At any rate, Nodera is not sure how long he would like to continue the symposium and remarked, half in jest, that an international conference may be a nice way to end the series with a BANG! rather than a whimper. [It is interesting that in the United States, the ninth of an annual numerical analysis symposium, especially one focused on numerical linear algebra and pde applications, would have a very large attendance. In my experience, in Japan there is emphasis on algorithms within the context of applications. DKK]

The conference opened with an audience of a little over 30 persons, and gradually the audience increased to about 50 by lunchtime and held steady for the remainder of the afternoon. As in most Japanese workshops, an informal short abstract book was handed out along with some reprints of papers. A more formal, bound proceedings booklet will be published at a later date. To obtain a copy, a very modest mailing and printing fee may be requested. For further information, please contact:

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Summary of Talks

Miyamoto and Tanahashi:

The talk was a preliminary report on numerical simulations of natural convections between two eccentric cylinders using generalized simplified marker and cell finite element method (GSMAC-FEM). The 3-D problem was reduced to 2-D by taking a cross-section. The simulation results agreed well with those from laboratory experiments. The main features agreed very well, and discrepancies could be attributed to the reduction of the problem to 2-D. In particular, the temperature profiles did not agree in some areas, but this had to do with 3-D currents and vortices that could not be modelled in 2-D. Professor Oyanagi (who recently moved from Tsukuba University to Tokyo University) commented that much more work needs to be done, particularly some in 3-D, before any concrete conclusions can be made.

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A regular, cylindrical mesh that was shifted to be eccentric (like the cylinders) was used. The video of simulation results was made by using software from the Kubota Corporation.

Summary of Nodera's talk:

Nodera presented some work done by his students using Latex. Although Tex and Latex were not designed with the primary intention of being used for drawing pictures, very fine results were obtained by his students (comparable to software designed specifically as a sketch pad or drawing tool.) Nodera also showed how pictures could be easily cut and pasted together within the figure environment by placing each picture in a box, using the tabular command, and treating each box as a subfigure. Unfortunately I didn't jot down all the details, but they will undoubtedly appear in the proceedings or in Nodera's next book on Latex Gems.

Nodera's talks (or perhaps his personality) always inspire the little imps in the audience to speak up during the Q&A session. This time the controversial questions were:

Q1: Some conferences now only allow submission of Latex/AMSTex/Tex formatted abstracts. Will this trend increase?

Q2: Will every mathematician be forced to learn Latex/AMSTex/Tex to survive?

Q3: Will Latex continue to be the dominating software for word processing to be used by mathematicians? If so, how long?

A1: The trend may increase slightly, but will not take over. The primary reason for this type of requirement is to help out the poor editor of a workshop.

A2: No one will be forced to, but it is clearly a useful skill. For older or theoretical mathematicians who have never even logged on, take heart. One of this reporter's best Latex students was a non-American, theoretical mathematician over 50 who had never touched a computer keyboard. He is now happily writing all papers and books using Latex and finds it to be an indispensable tool for communicating with his Ph.D. students over the network, especially when sabbaticals and business trips take him overseas. Latex is also good for accessing papers on-line using anonymous ftp.

A3: Latex/AMSTex/Tex will probably be the word processing tool used by most mathematicians for a long while; they will most likely take us into the next century.

Summary of Jea's talk:

Jea (who was visiting from Taiwan) was introduced as a former student of David Young who now does wonderful mathematics in her own right. And indeed we were not disappointed; Jea's talk took us on a journey from the history of Lanczos's work to her own. This was her second talk this week at Keio. Unfortunately, the sentences in the abstract for her talk were chopped by the word processor and didn't make sense, so I have listed the abstract from her

preprint that was distributed early in the morning. "In this paper we consider several methods presented by Cornelius Lanczos for solving nonsymmetric linear systems including the method of minimized iterations, the progressive algorithm, and the p-q algorithm. We describe the relations betweeen these methods and other iterative methods that have subsequently been developed. These methods include the Orthodir, Orthomin, and Orthores variants of the idealized generalized conjugate gradient (IGCG) method as well as three related methods including Lanczos/Orthodir, Lanczos/Orthomin and the Lanczos/Orthores method. It can be shown that Lanczos Orthodir is equivalent to the q-version of the p-q algorithm, the method of minimized iterations is equivalent to the p-version of the p-q algorithm and the Lanczos/Orthomin method is the same as the biconjugate gradient (BCG) method which is equivalent to the p-q algorithm."

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The proceedings are now available from Nodera at Keio. Jea did a healthy bit of advertising for a special centenary conference in honor of Lanczos later this year at the University of North Carolina.

Summary of Hasegawa's talk:

Hasegawa showed through examples how the same types of calculations, i.e., use of the same algorithm, can lead to different results depending on the details of the program code and the hardware. He also cautioned that some speakers will tend to show better results that support a method or theory, while others will tend to focus on the errors and mismatches; the same data presented by different speakers can leave the audience with very different impressions.

Summary of Ashby's talk:

Nodera introduced Ashby as a Ph.D. from Illinois who now works in the middle of a desert (saba-ku) in the United States as part of the SDI project at Lawrence Livermore National Laboratory. It was difficult to tell how much of the introduction is true [sic, DKK]. This was the second (more theoretical) talk by Ashby at Keio this week. It was clear and very well prepared. The abstract from Ashby and Gutknecht's talk is very long, so I have copied the abstract from his preprint instead.

Abstract from preprint of paper by Ashby and Gutknecht:

This paper explores the relationships between the conjugate gradient algorithms Orthodir, Orthomin, and Orthores. To facilitate this exploration, a matrix formulation for each algorithm is given. It is shown that Orthodir directly computes a Hessenberg matrix, H_k, at step k. Orthores also computes a Hessenberg matrix, G_k, which is similar to a Hessenberg matrix obtained from H_k by perturbing its last column. (This perturbation vanishes at convergence.) Orthomin, on the other hand, computes a UL and LU factorization of the perturbed H_k and G_k, respectively. The breakdown of Orthomin and Orthores are interpreted in terms of these underlying matrix factorizations. A connection with Lanczos algorithms is also examined, as is the special case of B-normal(1) matrices (for which efficient three-term CG algorithms exist.)

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Washio and Hayami's talk:

Ken Hayami and his colleagues from the NEC C&C Research Laboratories have consistently presented their very fine work at this symposium. Although all papers and abstracts submitted to Japanese workshops are in Japanese, he and his group do publish some of their work in English.

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Amano and Saito's talk:

The abstract is in Japanese; however, an English preprint of their work is listed in the references. Unfortunately, I have no address for Josei University or Toppan Insatstu. Their addresses might be obtained through Nodera or they may be listed in the formal proceedings to be published.

Chiba and Kako's talk:

Chiba is a second year Masters degree student at Saitama University. Kako is a member of the faculty of the Department of Computer Science and Information Mathematics at the University of Electro-Communications, nicknamed Dentsuu-dai by the Japanese. Professor Ushijima and colleagues at Dentsuu-dai have a fine tradition of research in MHD and have organized regular workshops and seminars on the topic and applied mathematics. Proceedings from the MHD workshops are published on a regular basis.

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Mei Kobayashi, born in Tokyo, Japan, graduated from Berkeley High School in 1977 and from Princeton University in 1981 with an A.B. in Chemistry. She attended the Harvard University Graduate School for Arts and Sciences in Chemistry for one year before returning to Berkeley. In 1984 she received a M.S. in Mathematics from Berkeley and later a Ph.D. in Applied Mathematics in 1988. Her research experience includes work, as a chemistry lab technician, in 1979 at the Lawrence Berkeley Laboratories (LBL) and in 1980-1981 at Princeton and as a research assistant at IBM in 1984 and LBL in 1987. She has been working at the IBM Tokyo Research Laboratory since April 1988.

THE ROYAL ADELAIDE HOSPITAL HYPERBARIC MEDICINE UNIT

Neal A. Naito

INTRODUCTION

The Royal Adelaide Hospital (RAH) Hyperbaric Medicine Unit (HMU), located in the southern Australian city of Adelaide, is the leading institution in the country in the area of diving and hyperbaric medicine. With a diverse program of medical treatment, teaching, diving emergency rescue coordination, and research, the HMU has played a major role in improving the safety of recreational and commercial diving in Australia. Its pioneering research into the pathophysiology of cerebral air embolism is helping to change the fundamental views of how this disease mechanism works. Currently, it has a unique working relationship with the two year old Royal New Zealand Navy (RNZN) Slark Hyperbaric Centre (SHC), whereby it provides training to RNZN personnel and access to its animal research laboratories. The RNZN facility in turn allows joint usage of its mixed gas capable dive boat and manned experimental diving laboratory. This article and the one following as well are the result of the author's past visit to both centers and discussion of their activities with their respective Directors.

ROYAL ADELAIDE HOSPITAL

Founded in 1841, RAH is the second largest hospital in Australia with approximately a 1,000 bed capacity. Situated adjacent to the University of Adelaide, RAH is one of three teaching hospitals associated with the University's School of Medicine and has all the services except obstetrics and pediatrics. The Institute of Medical and Veterinary Science (IMVS) is also nearby. RAH staff includes many world recognized authorities in various fields of medicine. A major tertiary referral center, it accepts patients from a large area including South Australia and the Northern Territories. RAH operates a well known trauma center and oversees the associated emergency transport system that includes helicopters. With these capabilities, RAH was an ideal place in which to organize a hyperbaric medicine unit.

HYPERBARIC MEDICINE UNIT

HMU was formed in 1985 under the cognizance of RAH, IMVS, and the Victorian Division of the National Safety Council of Australia (NSCA). The major initial funding for the multiplace chamber and other equipment was provided by NSCA. NSCA was a nonprofit quasi-governmental agency with the main purpose of organizing safety programs such as the formation of search and rescue teams or setting up recompression chamber facilities. However, the NSCA dissolved in 1988 because of financial difficulties. Consequently, the RAH, under the auspices of the South Australian Health Commission, assumed complete responsibility of HMU by placing it within the Department of Anaesthesia and Intensive Care. The founder of HMU was Dr. J E Gilligan, a noted intensive care specialist, recruited its first Director, Dr. D F Gorman. Dr Gorman's previous position had been with the Royal Australian Navy School of Underwater Medicine in Sydney. It was under Dr. Gorman's direction that HMU developed its leadership role in diving and hyperbaric medicine in Australia with a large commitment to research as a foundation.

In 1989, Dr. Gorman left HMU to start-up the RNZN SHC. Dr. Gorman is still a consultant to the HMU and spends several months a year in Adelaide overseeing the continuing animal research work in diving physiology and teaching diving medicine courses. The present director of HMU is Dr. J Williamson.

PERSONNEL

Recruited to head HMU by Dr. Gorman, Dr. Williamson is an anaesthetist with many years of experience using hyperbaric therapy to treat diving injuries and other illnesses in the Townsville area. He has previously attended both diving medicine courses at the Royal Australian School of Underwater Medicine and HMU. He is a world expert in the field of venomous marine life with a special interest in jellyfish. A former recreational diving instructor, he is very familiar with the health and safety aspects of SCUBA diving.

Within HMU, there are three other clinicians who practice with Dr. Williamson. They are Dr. C. Acott, Dr. R. Webb, and Dr. R. Capps. All are anaesthetists with many years of experience in the field of diving and hyperbaric medicine as well. Other full-time staff of HMU consists of a clinical nurse consultant, clinical nurse, a registered nurse, two recompression chamber operators, and a secretary. HMU also has two part-time registered nurses and a volunteer nursing pool of 26 available if there is a staffing shortfall.

To qualify to work in a hyperbaric chamber as a nurse requires passing a diving medical examination, a pressure test, and attendance at a one week introductory course in hyperbaric medicine. National licensing test is not required at this time. The chamber operators learned their positions through years of on-the-job training, either working in the military or the offshore oil industry as divers. The two full-time nurses at HMU are C. Pirone and A. Jones. The chamber operators are R. Ramsay and S. Goble, who learned their skills through years of on-the-job training, either by working in the military or in the offshore oil industry as divers. Since hospital based training on how to operate recompression chambers is presently in the planning stages, industry or the military continue to be the source for such personnel in medicine.

About research projects at HMU, Dr. Williamson directs the clinical investigations while Dr. Gorman and S. Helps, a Ph.D. candidate in animal physiology, oversee the lab animal experiments. All HMU staff personnel actively participate in research, whether it be setting up human trials or developing a new oxygen breathing apparatus.

FACILITIES

HMU has one double lock Drager recompression chamber. (See Fig. 1). It is equipped with closed circuit television monitors, an oxygen and C02 analyzer, C02 scrubber, and separate heater/chiller units. Chamber penetrations to allow for gathering of ECG, EEG, and other critical care data have been placed. Also available is the capability to handle mechanical ventilator patients inside the chamber. The chamber is capable to receive in transfer patients brought to the HMU in a portable chamber. Gas mixtures that can be used include air, oxygen, nitrox, and heliox.

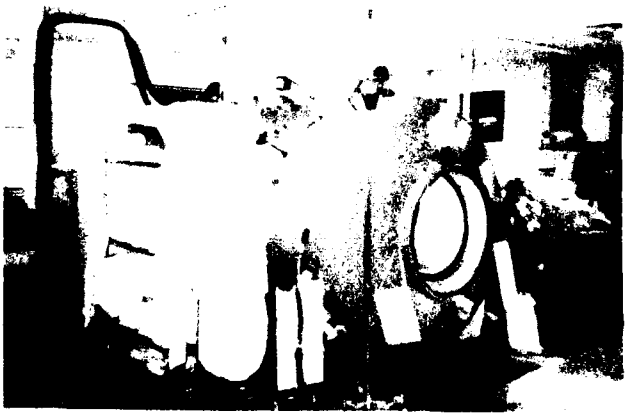

Fig. 1 — Royal Adelaide Hospital, Hyperbaric Medicine Unit (HMU) has one double lock drager recompression chamber

The chamber and associated support equipment such as compressors and gas bottles are situated in the basement of the hospital. Also attached are some clinical office space with the directors office several floors away. In the future, there are plans to build a consolidated unit next door to the intensive care unit with classrooms, overnight quarters, and additional office space. This scheme would facilitate better patient management, since many patients treated at HMU are already from intensive care or need to return there for hyperbaric therapy.

In addition to the recompression chamber facility, HMU has also a dedicated animal research laboratory. Equipment includes an animal microsurgical table, mechanical ventilator, blood gas analyzer, electronic monitors, electronic plotters, video record

er, and personal and laptop computers. Laboratory support from other hospital departments and the University is readily available. During my visit, the laboratory was set-up for using the rabbit brain as a model for studying arterial gas embolism.

FUNCTION

HMU has several roles, but the foremost is a hyperbaric medicine treatment center. In 1990, HMU treated 116 patients with the majority of them suffering from carbon monoxide poisoning related to smoke inhalation and diving injuries. Treatment tables used include the Royal Navy 61 and 62 that are similar to the U.S. Navy Table 5 and 6, respectively. For retreatments, oxygen tables are also used including an 18 m for 60 min followed by 30 min of decompression and a 10 m for 90 min followed by 30 min of decompression. The large number of diving injuries treated at HMU is caused by the great amount of sports and SCUBA diving done in Australia and by a burgeoning local inshore abalone harvesting industry.

To decrease the number of diving injuries, HMU has taken a leadership position by being actively involved in improving diving safety. Because of these efforts, most recreational diving instructional organizations require that a prospective student receive a physical examination performed by a physician trained in diving medical examinations prior to entering a course. HMU is also often consulted by government and industry groups for guidance on issues related to diving health and safety.

To improve treatment of diving injuries, HMU has become the headquarters for the Diving Emergency Service (DES), which works closely with the international Divers Alert Network system. Staffed by HMU physicians, DES provides 24 hour phone service to help coordinate national emergency assistance to persons with serious diving injuries. It can arrange for patients to be referred to one of Australia's eight other hyperbaric units for definitive care.

Better medical care for divers also involves training of physicians and allied health care workers in diving medicine. HMU conducts a medical officers course twice a year and a diving medical technician course three times a year. The medical officers course lasts for two weeks and consists of a didactic phase where the principles of diving and introductory hyperbaric medicine are taught, and a clinical phase where hands on training with the recompression chamber is given. The diving medical technician course is similar in scope with the addition of further clinical training in emergency resuscitation techniques. HMU has provided training to both civilian and military personnel from countries throughout the Western Pacific including New Zealand, Thailand, Singapore, and Indonesia.

Research at HMU covers both the clinical and basic sciences. The clinical work is focused mainly on problems associated with hyperbaric oxygen therapy and diving safety (See Table 1). HMU is currently coordinating large multicenter trials within Australia and looking at the efficacy of HBO in treating carbon monoxide poisoning and burns. Up to now most of the observations regarding the effectiveness of HBO in treating these two illnesses has been anecdotal or in small groups of patients. The effect of HBO on patients suffering from xerostomia is also being investigated. Diving safety is being looked at from an epidemiological standpoint where surveys of divers' attitudes regarding their sport or occupation is being conducted to try to discern injury inducing behavior. Prospective and retrospective analysis of DES cases is being done to look for trends that maybe contribute to diving accidents. Investigations of equipment design is also being performed as HMU personnel have explored ways to improve oxygen mask efficiency for portable first aid oxygen units.

Table 1 - Focus of Clinical Work on Problems Associated with Hyperbaric Oxygen Therapy

1. HBO and Xerostomia (Multi-center study).
2. Carbon monoxide off-gassing with HBO.
3. Pulse oximetry in carbon monoxide poisoning.
4. One hundred percent oxygen delivery apparatus.
5. Diving Incident Monitoring Study (DIMS).
6. Hyperbaric oxygen and Cystoid Macular Edema (Multi-center trial).
7. Long term outcome of HBO for osteo-radionecrosis patients.
8. Randomized controlled study of the efficacy of HBO in treating burn patients.

Basic science research at HMU has focused on three areas,

- the pathophysiology of cerebral arterial gas embolus,
- in vivo gas diffusion kinetics, and
- neuronal activity during injury.

Of these three fields of study, the investigation using a rabbit brain model to delineate the mechanism of injury caused by cerebral AGE has been the most exciting. Up to now, the accepted doctrine has been that cerebral arterial gas emboli (CAGE) cause injury through direct blockage of the blood vessel, and that bubbles that do not are of no concern.

Through exposure of the cerebrum of an anaesthetized and mechanically ventilated rabbit, serial measurements of cortical somatosensory evoked response, pial arteriole diameter, and cerebral blood flow (measured by hydrogen clearance) were obtained. (See Fig. 2). Results from the experiment revealed that injected carotid arterial bubbles small enough to cause only temporary or no mechanical obstruction still produce significant decreases in brain blood flow and function [1,2]. How this loss is probably mediated was well demonstrated when a rabbit made leukopenic chemotherapeutically, showed no changes in the above mentioned neurophysiologic parameters when microbubbles were introduced [3]. Thus, microbubble interactions with leukocytes and probably blood vessel endothelial cell walls play a central role in the evolution of symptoms caused by CAGE.

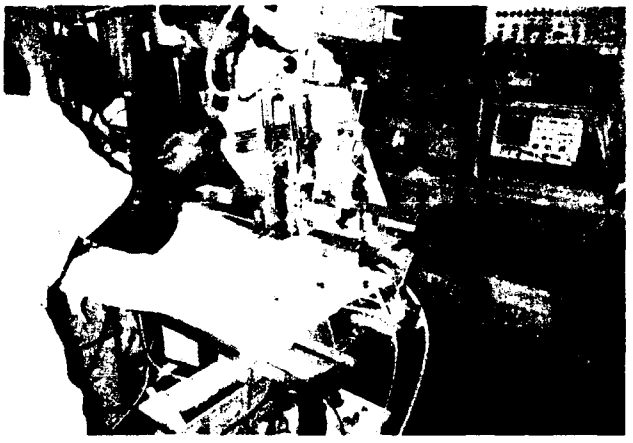

Fig. 2 — Serial measurements of cortial somatosensory evokes repsonse, pial arteriole diameter, and cerebral blood flow.

Consequently, the heretofore recommended treatment for CAGE of immediate pressurization of the patient to 165 ft probably is valid only for a certain small subset of patients that indeed have stoppage of blood flow, and symptoms have a rapid onset. The new findings open the way for possible adjunctive medicinal therapy that involves the use of directed antibodies or other agents against the mediators and products of the gas bubble, blood, blood vessel wall interactions.

Modern dive tables are based on the principle that different tissues of the human body absorb and release gas at varying rates. It was assumed that the longest time a gas would take to be completely excreted from the body would be one or two days. However, in an animal model involving a sheep with sampling catheters placed in numerous arterial and vascular sites developed by the Department of Anaesthesia and researchers from HMU, it was surprisingly discovered that some gases were being excreted up to several weeks later. The implication of this finding is that many of the mathematical equations used to predict off-gassing of substances in the body are probably too simplified with too few theoretical tissue compartments.

Finally, the other area of animal research being pursued at HMU has involved examining rat brain slice preparations for clues to the mediators of injury to neurons from ischemic insults that would be found in decompression illness or arterial gas embolus. Further delineation of the substances or processes responsible for neuron injury could lead to treatments that would be protective or regenerative of neurons exposed to low oxygen conditions.

CONCLUSION

In summary, the RAH HMU, in its short history of existence, has become the leading center in Australia in diving and hyperbaric medicine. Its strong research agenda provides the necessary foundation for it to carry out the rest of its other missions. With scientific funding limited in Australia because of Federal budget problems, its joint research efforts with the RNZN is an innovative solution that will be very beneficial to both organizations. To make contact with HMU, write to the following address:

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LCDR Neal Naito is currently assigned to the Naval Hospital, Oakland, California, as a resident in Internal Medicine. He was previously stationed at Submarine Group Seven in Yokosuka, Japan, as an undersea medical officer. After graduating from the University of California at Davis with a B.S. in Environmental Toxicology, he then attended the Uniformed Services University of the Health Sciences where he obtained his M.D. degree in 1986. He next did an internship in Internal Medicine at the Naval Hospital, Oakland, prior to receiving his training as an undersea medical officer at the Naval Undersea Medical Institute in Groton, Connecticut.

THE SLARK HYPERBARIC CENTRE

Neal A. Naito

INTRODUCTION

The Royal New Zealand Navy's (RNZN) Slark Hyperbaric Centre (SHC) is the only diving and hyperbaric medicine facility in New Zealand dedicated to research and medical treatment. Located at HMNZS PHILOMEL in Auckland, the center was established in 1989 under the leadership of, then Medical Directorate of the New Zealand Armed Forces, Surgeon Commodore P Robinson. Surgeon Commodore Robinson, a trained diving medical officer, selected Dr. D.F. Gorman to head the unit. Presently, the Director of Medical Services for the RNZN, Dr. Gorman holds dual citizenship in both New Zealand and Australia. This allowed him to become a surgeon commander in the Navy.

As reviewed in the preceding article about the Royal Adelaide Hospital (RAH) Hyperbaric Medicine Unit in Australia, the selection of Dr. Gorman provided the key link between the two facilities to share resources for training and research. There were several reasons that compelled the RNZN to organize a formal program in diving and hyperbaric medicine. There had been several serious naval diving accidents involving personnel, which had been caused by inadequate safety precautions or lack of ready access to appropriate medical treatment. This experience was mirrored in the civilian sport and occupational diving community as well, which was growing rapidly.

Also, the RNZN wanted to expand the type of diving it did to include surface supplied salvage diving and explosive ordnance disposal diving with mixed gas rebreathers. Finally, the direct civilian economic and humanitarian benefits of a Navy diving and hyperbaric medicine program was in keeping with the government's antinuclear and demilitarization policies.

PERSONNEL

An expert in pathology and treatment of cerebral arterial gas embolism, Dr. Gorman received his undergraduate degree in physics in 1974 and his medical degree in 1977 from the University of Auckland. Dr. Gorman did his postgraduate medical training in occupational medicine. Then he entered the Royal Australian Navy in 1980 and completed training in diving and submarine medicine while being assigned to the School of Underwater Medicine. It was during his tour at the School that he began his initial investigation into the underlying mechanisms of injury of cerebral arterial gas embolism while working on his Ph.D. thesis. Dr Gorman left the Navy in 1986 to head the RAH Hyperbaric Medicine Unit, and earned his Ph.D. in 1988 from the University of Sydney. He has written or coauthored over 82 medical publications in the area of diving and hyperbaric medicine including chapters in the authoritative textbook "The Physiology and Medicine of Diving." Presently, he is a civilian manager that oversees the center during the daytime. There are 15 diving medical technicians (nondiving trained) at the SHC, who provide medical treatment inside the recompression chamber, including intravenous therapies. They can also operate the recompression chamber under supervision. There are 34 Navy divers stationed at the nearby RNZN Dive School, who provide after-hours chamber coverage to the SHC and man the dive tender as well. Presently trained in almost all facets of diving including EOD, special warfare, and salvage, RNZN divers are also being qualified as DMTs to provide more complete on-site operational medical capabilities. Two diving medical officers are posted at the HMNZS PHILOMEL, with one currently on exchange as Officer in Charge of the School of Underwater Medicine in Sydney. In addition, two more medical officers are undergoing training in diving medicine.

FACILITIES

The Slark Hyperbaric Centre, which is located adjacent to the RNZN Hospital, was opened approximately 2 years ago and was named in honor of

Surgeon Commodore Tony Slark, the "father of diving medicine in New Zealand." It contains a state-of-the-art 10-man recompression chamber with full intensive care type monitoring capabilities including mechanical ventilators (See Fig. 1). It has a horizontal wet lock design with a NATO bayonet that allows for transfer of patients from portable recompression chambers. For on-site treatment of diving casualties, a transportable six-man recompression chamber and a one man recompression chamber are available.

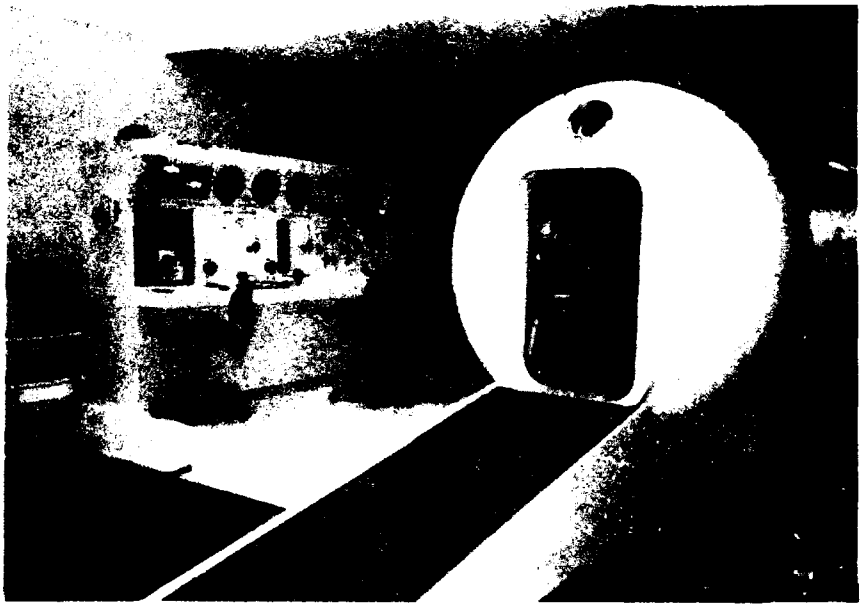

Fig. 1 — Fleet imaging facility pacific Yokosuka, Japan

For open ocean diving research, SHC personnel have access to the HMNZS MANAWANUI, a 1,000 ton diving tender that was purchased by the RNZN from a North Sea oil services company at a much lower cost than a comparable new ship was converted to requirements. The vessel is helium-oxygen, saturation capable, and can conduct wet bell operations to 90 msW. ROVs can also be operated off the ship. The recompression chamber on board is a standard 14-man three-compartment model with limited life support monitoring capability.

MISSION

The mission of the SHC is three fold. It encompasses medical treatments, instruction, and research. Currently, 50-60 diving casualties are treated at the Slark Hyperbaric Centre each year, while nondiving patients add another approximate 20 cases per year.

Medical officers are instructed with two introductory courses to diving and hyperbaric medicine, yearly. In addition, there are full time training positions for one RNZN and one RAN medical officer to work at SHC. Training of diving medical technicians is also done at SHC and occurs on a quarterly basis. The course is one month in duration with one week at Auckland and three weeks at Adelaide.

Research at SHC is primarily clinical in nature and most of the laboratory investigations are done collaboratively at the Royal Adelaide Hospital in Australia (See previous article entitled "The Royal Adelaide Hospital Hyperbaric Medicine Unit.") Current clinical research includes examining the use of color flow doppler for cerebral blood vessel bubble detection as a means of developing oxygen-helium decompression schedules; a prospective randomized trial of oxygen vs oxygen-helium in the treatment of decompression illness; prospective randomized controlled study of lignocaine infusions in the treatment of decompression illness; and a study of respiratory girdling and pulmonary barotrauma risk.

CONCLUSION

The RNZN Slark Hyperbaric Centre is one of the newest diving and hyperbaric medicine research centers in the world. Although its facilities and funding are limited in proportion to the overall small size of the New Zealand Armed Forces, it has managed to acquire the means to carry out an ambitious research agenda through a cooperative agreement with the RAN and the RAH. Guided by Dr. Gorman, the SHC can be expected to provide innovative leadership in diving health and safety matters to both the civilian and military diving communities in New Zealand. Contact with Dr. Gorman can be made through the following address:

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ENVIRONMENT 1993 SYMPOSIUM ON REMOTE SENSING IN ENVIRONMENTAL RESEARCH AND GLOBAL CHANGE, 3-6 MARCH 1993, HONG KONG

Representatives from China, Japan, Hong Kong, Norway, Taiwan, and the United States met at a Symposium and Workshop on remote sensing instrumentation and applications for use in environmental studies, focusing, where possible, on examples from the western Pacific. Some 20 papers were presented orally (21 in the Proceedings Volume) over two days, 3-4 March 1993, at the Hong Kong University of Science and Technology. An additional half-day, 6 March 1992, was used for a discussion workshop. Major topics included Application in Oceanographic Research (9 papers) and Global Change (8 papers). Highlights included summaries of future programs such as SeaWifs, new and developing instrumentation such as SAR with proposed applications to climatic and environmental studies, and discussions of techniques of validation of satellite data (sea truthing by ships, buoys, sondes) and verification of algorithms.

Pat Wilde

INTRODUCTION

The new Hong Kong University of Science and Technology (HKUST) was the site where "Environment '93: Symposium on Remote Sensing in Environmental Research and Global Change," 3 to 6 March 1993, was hosted. The purpose of the Symposium was two fold:

(1) to assess the status of environmental remote sensing both globally and specifically in the east Asian area; and

(2) to see what role the new University might play in the development of remote sensing research. The Hong Kong University of Science and Technology is still building in the Kowloon hills on Clear Water Bay and is now only in its second year of operation. Presently, it has 2500 students with a target of 7 to 8,000 students and a student-faculty ratio of 11:1. In fact, this symposium opened the second phase of the initial three phase construction of the new campus. Uniquely funded by funds from the Hong Kong Jockey Club, the university is growing rapidly, and some 10 faculty members are hired each month. The facilities are new and very high technology with all classrooms and the student dormitory rooms connected with an optical fiber LAN network.

The symposium consisted of two days of formal presentations followed by a half-day workshop. Its objective was "to identify and summarize the potential contributions of remote sensing technology to environmental issues in the western Pacific region during the next five to ten years."

PRESENTATIONS

The program was divided into four sessions:
- Keynote Speech;
- Overview (3 papers);
- Applications in Oceanographic Research (9 papers); and
- Global Change (8 papers).

KEYNOTE SPEECH

Dr. John S. Theon, chief, Atmospheric Dynamics, Radiation and Hydrology Branch, Earth Science and Application Division, NASA, talked on "The NASA Earth Observation Program: Global Change and Remote Sensing." His address focused on NASA's "Mission to Planet Earth" and its objective to make the long-term observations required to ascertain the impact current changes will have on the climate. The goal is to be achieved through analysis of observations, modelling, and eventually predicting climate and climate change. The observations, per force, must be by remote sensing as the only practical scheme to observe the whole Earth for a decade or more to establish the baseline for estimating the changes. Dr. Theon described the various systems to be used in the program and called for international cooperation in implementing the program.

Unfortunately, like many so-called high-technology approaches to assess Earth scale issues, this program tends to ignore previous work and other disciplines for the sake of instrumentation. NASA's Mission to Planet Earth has a serious flaw in ignoring the geologic record of climate change. As bad or as incomplete as the geologic record is, is the only real record of the Earth's climate. Suggesting that even a ten year record of real-time observations, although unquestionably needed, can act as a baseline to assess climatic processes with time scales of various lengths is scientific grantsmanship of the first order.

OVERVIEW

The planned overview talk by Dr. Xinnian He, Institute of Remote Sensing of Application of the Chinese Academy of Sciences, was not given orally. The talk was included in the proceedings and discusses "Airborne Remote Sensing System of Chinese Academy of Sciences (CASARSS)." The system uses two Cessna Citation S/II airplanes as the platform. The instruments flown include: 19-channel infrared, thematic infrared, thermal infrared, 64-channel imaging spectrometer, multi-band camera, X-band side-looking real aperture radar (SLAR), synthetic aperture radar (SAR), airborne spectrometer, X-band scatterometer, multiband microwave radiometer, and a laser altimeter. The instruments are connected by a microcomputer based monitoring system. The complete system is used for resource studies, environmental monitoring, urban management, disaster monitoring, crop estimation as well as in research.

Professor Cho-Teng Liu, National Taiwan University, gave the overview talk on "Remote Sensing in Oceanographic Research in Taiwan." The program that began in the 1980's combined airborne and satellite data for applied purposes. Airborne techniques were used to monitor power plant effluent, long-shore sediment drift, and plumes from polluted rivers. Satellite information was used to "show the erosion and accretion of offshore sandbars." More recently, NOAA data have been used to study sea surface temperatures, chiefly in the region north of Taiwan where a cold water dome is a region of high-nutrient content, and thus an area of great fishing potential. Studies are ongoing on the interaction of the thermal dome and the Kuroshio current. This intensive observation program (IOP) is scheduled for September 1992 and March 1993. Studies are also on-going west of Taiwan looking at the boundaries between the China Coastal Current and a branch of the Kuroshio. Sea surface temperature anomalies monitored by satellite are being used to trace these current interactions.

The last overview presentation was by Dr. A. T. C. Chang of NASA's Hydrological Sciences Branch on "Space-borne Remote Sensing Sensor- Past, Present, and Future." The talk gave a brief history of various packages starting with TIROS-1 in 1960. Optical sensors discussed include: Advanced Very High Resolution Radiometer (AVHRR), Multi-Spectral Scanner (MSS), Return Beam Vidicon (RBV) camera, Thematic Mapper (TM) and the upcoming Moderate Resolution Imaging Spectrometer (MODIS) that has 36 spectral bands from 0.4 to 14.2 μm. Thermal infrared sensors mentioned include: Advanced Space-borne Thermal Emission and Reflective Radiometer (ASTER) for the Earth Observation System (EOS) series of satellites. The ASTER system will have a resolution of 15 to 90 m and be operated in three visible and near infrared (VNIR) bands between 0.5 and 0.9 μm; six short-

wave infrared (SWIR) channels between 1.6 and 2.5 μm; and five thermal infrared bands between 8 and 12 μm. Microwave sensors mentioned include: Electrically Scanned Microwave Radiometer (ESMR) and Nimbus E Microwave Spectrometer (NEMS) from Nimbus-5; Scanning Multichannel Microwave Radiometer (SMMR) from Nimbus-7 and Seasat-A; the Defense Meteorological Satellite Program-Special Microwave Imager (DMSP-SSM/1); and for EOS, the Multichannel Imaging Microwave Radiometer (MIMR). The MIMR system will operate in six frequencies in the range of 6.8 to 90 GHz, with a swath width of 1400 km and an incidence angle of 50° to provide three day coverage of the Earth. This system will provide much needed hydrologic data. Future developments are expected in lidar for atmospheric sounding using Raman scattering.

APPLICATIONS IN OCEANOGRAPHIC RESEARCH

These series of sessions were led off by Prof. James Yoder, University of Rhode Island, with a discussion about the "Scientific Applications of Sea Wide Field Sensor (SeaWifs) Imagery." This system, to be launched in August 1993, is sponsored by a private company Orbital Sciences Corporation, which will sell the real-time high resolution (1 km) wide-band ocean color scanner data. Qualified researchers will be able to obtain 4 km data in nonreal time relatively cheaply. SeaWifs will have the same visible bands as the Coastal Zone Color Scanner (CZCS) that died in 1986, with bands centered near 443, 520, 550, 670 nm and two additional visible bands at 412 and 490 nm plus additional near infrared channels at 765 and 865 nm. The additional channels will be used to assess the atmospheric correction and chlorophyll algorithms. The orbit is set to provide two-day coverage of any location on Earth. Professor Yoder presented some data on coccolith blooms in the Atlantic obtained from analysis of the CZCS satellite pictures as an example of how these data may be used in climate studies. Coccoliths are a major fixer of carbon dioxide in the ocean, converting it into calcium carbonate much of which is deposited on the seafloor, thus removing it from the short term atmospheric cycle.

Professor Dana Kester, also of the University of Rhode Island, presented a paper entitled "Chemical and Biological Remote Sensing of the South China Sea: Satellite and in situ Observations." The Coastal Zone Color Scanner (SZCS) images were reexamined in this region, and monthly "nearly cloud-free images" were reconstructed. The South China Sea has highly variable color sources including chlorophyll, suspended particles from rivers, and organic substances "yellow substances or Gelbstuffe." Because of the lack of in situ data, it was difficult to separate out the components just by using the standard chlorophyll algorithm. This is particularly valid for the apparent color "high" values in December, which intuitively seem unrelated to biological activity. An appeal for Volunteer Observing Ships (VOS) with automated analysis for chlorophyll and nutrients and expendable drifting buoys was made to be put in place before the SeaWifs data come on line, so that the remote sensing data can be calibrated better for local conditions.

Professor Delu Pan, Second Institute of Oceanography, People's Republic of China, continued on the previous theme of the problem of a proper color algorithm to interpret satellite data in his paper "Ocean Colour Remote Sensing for Marine Environment." He reviewed the various algorithms of the three major color contributors and suggested that inverse modelling might be used to separate out the effects of each. Various examples of the use of ocean color were shown from off the Minjiang River into the East China Sea, off Vancouver Island, Canada, the Gulf of Bohai and coastal waters of China, and in the North Sea off Germany. Inverse modelling was applied to the North Sea data. Again, the plea for more and more geographically consistent and persistent Sea Truth data were made.

Dr. Akira Harashima, National Institute for Environmental Studies, Japan, showed how such Sea Truth measurements are being made by "Continuous Marine Biogeochemical Monitoring by Japan-Korea Ferry Boat for the Validation of Ocean Color Remote Sensing." This operation uses a Volunteer Observing Ship (VOS) that travels twice weekly between Kobe, Japan, to Pusan, Korea, it covers about 200 km. The parameters monitored are seawater temperature, salinity, pH, fluorescence, and dissolved nutrients (nitrite, nitrate, ammonia, phosphate, and silica.) The pumps run at 15 to 20 l/min and the chemicals are automatically sampled at a spatial rate of about 100 m with the mean ship speed at 20 kn. The filtered samples are analyzed at the laboratory and not on shipboard. This is an excellent example of both international cooperation, in this case between Japan and Korea, and obtaining baseline data prior to the launch of SeaWifs.

Not presented orally, but included in the proceedings was a paper by Dr. Xuelian Chen and Dr. Dan Luo of the Scientific Research Institute, Pearl River Water Resources Commission on "Remote-Sensing Analysis of the Environmental Change in the area of the Pearl River Estuary, Hong Kong and Macao." This paper briefly discusses the enormous changes in the Pearl River Estuary caused by the development of shore based industrial and land reclamation projects and attendant water pollution. Remote sensing techniques are being used to monitor both the natural changes and variations caused by the tides as well, and man-made effects on sediment transport, nutrient supply, and pollution. Crisp color photographs taken by satellite and high flying aircraft using various sensors illustrate the conditions in the estuary.

Dr. Antony K. Liu of the NASA/Goddard Space Flight Center discusses "Synthetic Aperture Radar of Ocean Applications." This technique called SAR measures microwave backscatter and can be used to distinguish surface and internal waves, wind patterns, oceanic fronts, films, water current fields, shallow bottom topographic features, and mesoscale eddies. This method, unlike visible band sensors, is not affected by clouds or darkness and thus is very useful not only in normally cloudy areas but in high-latitude winters, where daylight hours are short or nonexistent. A SAR instrument has been up and running since July 1991 on the ERS-1 satellite. An example of the application of SAR data was given for the Fisheries Oceanography Coordinated Investigation (FOCI) carried out in the Gulf of Alaska, for the identification of eddies, fronts, and currents that transport larvae to the various nursery fishery grounds in the area. Real-time SAR images were used for the development of recruitment models.

Continuing the theme of operations using SAR in high latitude where both clouds and visible light can be limited, Dr. Johnny A. Johannessen, Nansen Environmental and Remote Sensing Centre, Bergen, Norway, gave an example of "Monitoring and Modeling of the Marine Coastal Environment: A Conceptual View for the Future." He gave the results of the Norwegian Continental Shelf Experiment (NORCSEX'91) that was a validation experiment of the ERS-1 SAR images off the coast of Norway. Several examples were given of the combined use of satellite images in real time to vector research ships to validate features seen on the images. SAR images are able to distinguish features such as water current fronts and eddies, natural slicks and oil spills, internal waves, the wave length and travelling direction of wind waves and swell, as well as wind fronts and wind patterns. Dr. Johannessen and his group are proposing to integrate satellite SAR and other sensor images such as from SeaWifs and TOPEX-Poseidon, with shipboard measurements to provide a more complete physical-chemical-biological monitoring scheme in this area.

A discussion of the finer scale oceanographic features was provided by Prof. Jin Wu, Air-Sea Interface Laboratory of the University of Delaware. Prof. Wu described his test facilities including an at-sea tower that is used to validate various instruments and "tune" algorithms related to wind-wave phenomenon. His group is looking at three types of remote sensors: altimeters, scatterometers, and radiometers. Altimeters are sensitive to microwave return from ripples. Scatterometer values are shown to be related to the Bragg equation and are a function of the wave number slope spectrum. This device can be used to "measure" oil pollution as films damp waves. Altimeters may also be used to distinguish actually rain falling on the ocean as rain drops suppress wave action.

Sea truthing of various satellite sensors using buoys and ship observations was presented by Prof. Hiroshi Kawamura of the Center for Atmospheric and Oceanic Studies of Tohoku University, Japan, in the paper: "Validation Results of the Satellite-derived Parameters for the Oceanography in the North Western Pacific Ocean." The comparison with satellite data is made from data from four Ocean Data Buoys (three in the Pacific Ocean and one in the Sea of Japan) arrayed around Japan and from the Ocean Mixed Layer Experiment (OMLET) cruises. The buoys measure 11 variables every three hours. On the cruise, physical data and radiation fluxes were measured south of Honshu Island. The results were: Short Wave Radiation- rms error = 20 W/m^2; Cloud Amount- rms error = 10.5%; Long Wave Radiation- rms error = 14 W/m^2; Multi Channel Sea Surface Temperature (MCSST)- high resolution data rms error = 0.43°C, global (weekly average) = 0.98°C; Wind Speed from GEOSAT Altimeter- rms error = 2.1 m/s; Wind Speed from Special Scanning Microwave Imager SSMI on the Defense Meteorological Satellite Program (DMSP) satellite- rms error = 2.21 m/s; Wind Vector from Active Microwave Instrument (ARI): Wind Speed- rms error = 1.90 m/s, Wind Direction- rms error =

44.2°; Atmospheric Water Vapor by SSMI/DMSP- rms error = 1.48 g/kg; Wind Waves by GEOSAT Altimeter- rms error = 0.48 m.

GLOBAL CHANGE

Dr. William P. Chu of NASA Langley Research Center gave the first talk at the Global Change Sessions, on "Remote Sensing Using the Solar Occulation Techniques". He discussed the results of data from the Stratospheric Aerosol Measurement II (SAM II) and Stratospheric Aerosol and Gas Experiment I (SAGE I) measuring globally the vertical distribution of aerosol, ozone, water vapor, nitrogen dioxide, and cirrus clouds. This method differs from other systems that have to be validated from ground bases, in that the calibration light source is the sun and the technique is self-calibrating. Other validations of the profiles have been made by using lidar and balloon and rocket sondes. Dr. Chu presented some interesting profiles of the spreading of aerosols from Mount Pinatubo based on such measurements, indicating their use in global climatic studies.

Focusing on Earth-surface derived ozone measurements, Dr. Jack Fishman, also of NASA-Langley Research Center, presented a talk on "Identification of Global Smog Deduced from Analyses of Satellite Data Sets and Ozonesonde Measurements." Tropospheric ozone, dubbed Global Smog, has been monitored by using the Total Ozone Mapping Spectrometer (TOMS) and from SAGE, discussed in the previous talk by Dr. Chu. Total ozone in the atmosphere is 300 Dobson units (1 D.U. = 2.69 * 10^16 molecules of ozone/cm^2.) Of interest, is the high anthropogenic contribution of ozone at low latitudes caused by agricultural burning, both from development of new agricultural land by burning the rain forests but also by annual burning of stubble etc. of existing fields. This is a common practice in the tropics to fertilize the generally poor soil and to prepare the fields for new plantings. This explains the high values of ozone spotted by satellites over Ascension Island in the middle of the South Atlantic far from industrial sources of ozone concentrated in the Northern Hemisphere.

Dr. William K. M. Lau of NASA-Goddard Space Flight Center discussed the use of satellite in probing the hydrologic cycle by measurements of water vapor. Using El Nino-Southern Oscillation (ENSO) as an example, Dr. Lau discussed the various instruments and programs to monitor climate and the global hydrologic cycle. Sea surface temperatures are derived from infrared sensors such as NOAA's Advanced Very High Resolution Radiometer (AVHRR), TIROS Operational Vertical Sounder (TOVS), and microwave instruments like the Scanning Multichannel Microwave Radiometer (SMMR). The advantage of microwaves sensors is that they can see through clouds, which are present over large areas of the surface. Precipitation can be estimated by using a combination of visible and infrared techniques; although the present methods have serious problems and are difficult to validate. Global precipitation maps have been produced from data from Electrically Scanning Microwave Radiometer (ESMR) from Nimbus-5, (SMMR) from Nimbus-7, and SSM/I from the Japanese Defense Meteorological Satellite Platform. It is hoped that the Tropical Rainfall Measuring Mission (TRMM) that is a joint US-Japan effort scheduled for 1996 will improve the techniques. Evaluation of the effect of clouds continue to be a major unsolved problem in the determination of surface radiation budgets. The different types and altitude of clouds have various impacts on the heat balance, not always in the same direction. Cloud classification algorithms have been developed from the Nimbus-7 Temperature Humidity Infrared Radiometer (THIR) and from TOMS. This general problem is being studied by the International Satellite Cloud Climatology Project (ISCCP). As wind speed has a major effect on evaporation, sensing of this parameter is also critical to the development of climatic models. In general this is estimated by microwave backscatter using various scatterometers. Sea level, which is important in geostrophic ocean circulation models, is monitored by satellite altimeters. On the global scale, knowledge of the circulation at various time scales is important to the understanding of the heat flux and long term climatic effects.

Following the theme of the previous paper, Dr. W. Timothy Liu, Jet Propulsion Laboratory of the California Institute of Technology, focused attention on "Spaceborne Scatterometer in Synergistic Studies of Global Change". He discussed the NASA scatterometer (NSCAT) that will be launched with the Japanese Advanced Earth Observing Satellite (AEDOS-1) scheduled for launch in 1996. This system with the Advanced Microwave Scattering Radiometer (AMSR) planned for AEDOS-2 will measure sea surface temperature, surface wind speed, water vapor under clear and cloudy skies. From these measurements, evaporation and precipitation can be computed. These measurements

combined with the proposed Ocean Color and Temperature Scanner (OCTS) and the Global Imager (GLI) also planned for the AEDOS satellites will add the capability to observe the ocean's thermal and biological response to the surface wind-driven forcing. Tests were run comparing temperatures derived from two wind stress field evaluations (SSMI and the European Center for Medium Range Forecast: ECMRF) for the Ocean General Circulation Model (OGCM) spun up for 3.5 years to reach a quasi-equilibrium seasonal cycle. The AVHRR temperature data were used as the standard for observation. Agreement for sea surface temperature was good polar-ward of the subtropics (above 15°) but was poor in the equatorial zone.

The ever present problem of clouds and their formation was addressed by Dr. Man Li Wu, NASA-Goddard Space Flight Center, in her presentation: "Effect of Pollution on Cloud Condensation Nuclei, Cloud Properties and Rainfall." The results of eight cruises in the western tropical Pacific on the PRC research ship XIANGYANGHONG 14, studying aerosols and then comparing these data with cloud observations from satellites was discussed. The aerosols trapped were chiefly sulfates with biogenic sulfate particles 12% (El Nino - warm anomalies) and 40% (La Nina - cold anomalies) of the concentration of anthropogenic sulfate particles.

On a much smaller spatial scale from the above regional and global discussions in the above papers, Dr. Robert L. Spellicy of Radian Corporation described systems for detection of speciated organics etc. in the environmental monitoring of industrial chemical plants, stack effluent, and petroleum refineries. His paper "Ground-Based Optical Remote Sensing for Environmental Applications" discussed the use of optical "fences" that surround the plant, and reactor vessel to provide serial data for emission monitoring, detecting of fugitive emissions, and accidental release. The fences can use both or either infrared and ultraviolet spectroscopic methods depending on the need. Commercial units available include Fourier Transform Infrared (FTIR) and Ultraviolet Differential Optical Absorption Spectroscopy (UV-DOAS) and Gas Filter Correlation (GFC) spectrometer system. Other systems under consideration are Non-Dispersive Infrared (NDIR), Lidar systems (DIAL) and diode laser systems. Many of these systems are being used in advance of any legal requirement as a defense against lawsuits as well as a method to improve plant efficiency and maintenance. Distances up to 1 km can be covered by one set of detectors.

Dr. Tung Fung, Chinese University of Hong Kong, examined a local application of remote sensing in his presentation: "An Assessment of Hill Fire Impact in Country Parks with Spot HRV Images." Some 40% of the land area of Hong Kong is park land. With its high population, it is imperative for Hong Kong to maintain these parks for recreations purposes. Hill fires are significant problems. This discussion was about the use of SPOT High Resolution Visual images to make a geographically useful database to develop a fire prevention strategy. The multispectral images are classified by vegetative types and merged with topographic and cultural information onto a computer retrievable spatial database. Prior and frequent burn areas along with types of vegetation burned are thus identified.

The final paper of the formal sessions was by Dr. Fuk Li, Jet Propulsion Laboratory of the California Institute of Technology on "Spaceborne Imaging Radars for Earth Remote Sensing." This provided a brief summary of activities on Synthetic Aperture Radars (SAR) at the Jet Propulsion Laboratory. The latest system is the shuttle borne imaging radar (SIR) model C (L and C band), which will be used in conjunction with the European developed X-band SAR (XSAR) in future space shuttle flight scheduled for 1994. SAR systems have the potential to monitor ecosystem dynamic studies including green biomass to total biomass, the now difficult to measure soil moisture, plus fine scale mapping of sea ice (ice type, age, and concentration). The data intensive processing require complex facilities at a ground station such as the present one in Alaska mentioned in the above paper by Dr. A. K. Liu.

WORKSHOP

The meeting ended with a half-day workshop with the objective "to identify and summarize the contributions of remote sensing technology to environmental issues in the western Pacific region during the next five to ten years." The panel included Dr. Dana Kester as Chair; Jay-Chung Chen, Hong Kong University of Science and Technology; Akira Harishima, National Institute for Environmental Studies, Japan; Huasheng Hong, Hong Kong University of Science and Technology; Johnny A. Johannessen, Nansen Environmental and Remote

Sensing Centre, Norway; Cho-Teng Liu, National Taiwan University; Delu Pan, Second Institute of Oceanography, People's Republic of China, and John S. Theon, NASA, U.S.A. Each panelist gave a brief summary of his views and experience emphasing

(1) problems,
(2) existing capabilities,
(3) planned enhancements, and
(4) obstacles.

These findings will be produced in a final report to HKUST. Some of the problems discussed included the nonavailability of the Japanese satellite data to anyone except the original investigators. This was perceived as a "start-up" problem that will eventually be solved permitting open use. There was a discussion of the availability of SeaWifs real-time data for science purposes including a special license at a discount from the commercial rate.

SUMMARY

The tenor of the meeting was optimistic with both near-term and long-term cooperation among the scientists of many nations seemingly assured. Unquestionably, the United States, with NASA, is the technological leader in both hardware and analytical use. However, Japan and eventually China are developing a significant role as their own programs mature. Both China and Japan are taking a healthy inquiring stance with respect to interpretation, particularly with respect to color imagery algorithms running validation tests. One difference between the attendees from the United States and the other countries was the predominance in the U.S. delegation of satellite instrument and theoretical people, whereas the other countries were represented by actual environmental users of the data. This may be a deja vu feeling of another technology transfer of U.S. instrumental know-how, while the actual applied uses of the data are developed elsewhere. This, I am sure, reflects the partition of funds in these countries. As a marine scientist as well as a geologist, I am concerned that not enough attention or money is paid in the United States to fields with experience in the environment in favor of high-tech rhetoric to support instrument development glibly directed towards poorly defined "climatic" problems. Here in Asia and also apparently in Europe, application of remote sensing data seems to take precedence over newer and better gizmos. Obviously both approachs should be balanced if actual environmental problems are to be ameliorated. The Hong Kong University of Science and Technology is to be congratulated for putting on such a professional international meeting at such a young school. The size was just about right, as I was able to talk to a fair number of the participants, including the observers from the Hong Kong environmental agencies. For those interested, a copy of the bound proceedings, including many color photographs, is available from the University at Hong Kong at HK$235 per copy, or about US$30. That is a real bargain, thanks to the Jockey Club and the Hong Kong Chamber of Commerce that partially funded the conference.

Dr. Pat Wilde is an oceanographer-marine geologist currently serving as liaison scientist for Ocean Science and Engineering for the U.S. Office of Naval Research Asian Office in Tokyo. He is concurrently, a lecturer in Ocean Engineering at the University of California, Berkeley.

Dr. Wilde received his B.S. in Geology (Magna cum Laude) from Yale University in 1957. He worked for the Exploration Division of Shell Oil Company from 1957 to 1959 as a geologist. In 1959, Dr. Wilde returned to academia receiving his A.M. in Geology in 1961 and his Ph.D. in Geology in 1965 from Harvard University. While at Harvard, he also was a Graduate Research Geologist at the Scripps Institution of Oceanography working on the sedimentology of deep-sea fans. In 1964, Dr. Wilde joined the Engineering Faculty of the University of California, Berkeley and was Chairman of the Ocean Engineering Program from 1968 to 1975. In 1975, he joined the Lawrence Berkeley Laboratory and from 1977 to 1982 was Head of the Marine Sciences Group, whose major task was the environmental studies associated with the Ocean Thermal Energy Conversion program of the Department of Energy. In 1989, he received the Humboldt Foundation Senior Prize and spent a year in residence at the Institute of Geology and Paleontology at the Technical University of Berlin, Germany.

RESEARCH DEVELOPMENT CORPORATION OF JAPAN (JRDC) 9 MARCH 1993

A description of how the Research Development Corporation of Japan (JRDC), works in enhancing Research and Technological Development is provided.

David K. Kahaner

1. INTRODUCTION

Most of the following material was based on discussions with, and material provided to me by

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The Research Development Corporation of Japan (JRDC) is a key organization for implementing policies for the Science and Technology Agency (STA). STA is the science agency that is directly under the Prime Minister's office, rather than being a separate ministry under the Cabinet. Funding for JRDC's activities is provided by the Japanese government. Activities are associated with the overall development of the science and technology promotion systems in three main areas:

- basic research,
- technology transfer, and
- international research exchange.

JRDC was established in 1961 as a Technology Transfer program to nurture technology in Japanese industry based on research that was being done in the national laboratories and universities. A distinctive feature of this system was to promote and organize technology transfer by linking industry, national laboratories, and universities. Later, its focus changed to one of strengthening international cooperation. In 1981, JRDC began the Exploratory Research for Advanced Technology (ERATO) program to promote new basic research by emphasizing individual researchers and by forming research teams drawn from industry, academia, government, and abroad. In 1989, JRDC began an International Joint Research program and, in cooperation with the Science and Technology Agency (STA), the STA Fellowship program. In 1991, JRDC began the Precursory Research for Embryonic Science and Technology (PRESTO) program to promote basic research by individuals.

The International Joint Research program, as the international version of ERATO, started in 1989, sets up cooperative basic research projects among JRDC and foreign research organizations based on the principle of equal sharing of costs and facilities. In 1991, JRDC began PRESTO in order to provide individual researchers with opportunities for conducting precursory creative research that cannot be easily carried out within their own organizations.

Common to these programs are the emphasis on new, open-ended research and on talented key individuals, the direct hiring of young researchers, and the location of laboratories to benefit the projects. ERATO applies these principles to projects consisting of fifteen to twenty young researchers. International Joint Research program extends them to international research cooperation. PRESTO applies them to individual research.

During the past few years JRDC's operating budget was as follows.

1990: Japanese¥14.5B
1991: Japanese¥15.8B
1992: Japanese¥17.1B
1993: Japanese¥23.2B (19.5+3.7)

(NOTE: 23.2B was proposed but is likely to be approved. This figure includes 3.7B for expenses associated with moving JRDC's headquarters from its present location near the Diet Building to one in the northern portion of Tokyo (Kawaguchi).)

2. BASIC RESEARCH PROJECTS

JRDC promotes basic research through three programs, Exploratory Research for Advanced Technology (ERATO) and its international version, the International Joint Research Program, and Precursory Research for Embryonic Science and Technology (PRESTO).

(a) ERATO

ERATO projects are strictly limited to five-year terms, and give selected individual researchers the chance to develop their own ideas in flexible research teams. JRDC selects key individuals that have insight and leadership as project directors. These directors assemble groups of talented, budding young researchers drawn from industry, academia, government, and abroad to work together in laboratories that are located to best serve the group.

ERATO begun in 1981, and has its best organizational analogy in off-broadway theater. JRDC acts as producer in selecting directors who in turn recruit, motivate, and guide young scientific performers in researching a new theme. The directors and their research themes are selected by JRDC based on their attractiveness to young researchers and the approval of the Research and Development Council of JRDC. Directors must have real insight into the research theme and be able to motivate the fifteen to twenty young researchers that the director will personally recruit to the project. In other words, the focus of each ERATO project is its director. A list of these projects and their directors is given below. (Earlier, I reported on ERATO and one specific project, the Quantum Magneto Flux Logic Project under E. Goto, see for example "cpc", 3 Jun 1991.)Research themes are multidisciplinary and serve only as motifs for open-ended research. Projects are strictly limited to five-year terms with total budgets of about Japanese¥1.5B to 2.0B. Research is carried out in rented laboratories located in universities, industry, and other institutions to serve the directors. The use of rented space helps to enforce the temporary nature of the projects. JRDC has no research facilities of its own but provides the Directors with administrative and other support.

Young Ph.D. level researchers are drawn from industry, academia, government, and overseas; they are hired by JRDC on yearly renewable contracts. Results of the project are the shared property of JRDC and the researchers. Patent rights may be equally shared among JRDC and the project members directly responsible for the work.

1. Number of operating projects 17
2. Number of research groups 51
3. Number of locations 30
4. Research personnel (below)

Home Institution	Industry	Univ.	Nat Lab	Others	Indiv.	Foreign	Total
Research Personnel	67 (295)	2 (10)	1 (8)	1 (18)	95 (243)	37 (95)	203 (638)
Number of Institutions	50 (146)	2 (9)	1 (4)	1 (6)	-	15 (26) Countries	- -

(NOTE: Numbers in parenthesis are cumulative over ERATO history through 1/93)

ERATO PROJECTS

Term, director (institution) and theme are listed below:

81-86 Dr. Chikara Hayashi (Chairman/ULVAC Co.):
Ultra-Fine Particles
Prof. Tsuyoshi Masumoto (Tohoku Univ.):
Amorphous & Intercalation Comp
Prof. Naoya Ogata (Sophia Univ.):
Fine Polymers
Prof. Junichi Nishizawa (Press, Tohoku Univ.):
Perfect Crystals

82-87 Prof. Denichi Mizuno (Teikyo Univ.):
Bioholonics

83-88 Dr. Ossmu Hayaishi (Dir, Osaka Biosci Institute):
Bioinformation Transfer

84-89 Prof. Koki Horikoshi (Tokyo Institute of Technology):
Superbugs

85-90 Prof. Haruo Kuroda (Univ. of Tokyo):
Solid Surface
Mr. Shoichiro Yoshida (Managing Director, NIKON Co.):
Nano-Mechanism

86-91 Prof. Eiichl Goto (Kanagawa Univ.):
Quantum Magneto Flux Logic
Prof. Hirokazu Hotani (Telkyo Univ.):
Molecular Dynamic Assembly
Prof. Humio lnaba (Tohoku Univ.):
Biophoton

87-92 Prof. Junichl Nishizaws (Pres, Tohoku Univ.):
Terahertz
Dr. Mitsuru Furusawa (Board Director, Daiichi Pharmaceutical Co., Ltd.):
MorphoGenes
Prof. Toyoki Kunitake (Kyushu Univ.):
Molecular Architecture

88-93 Prof. Hiroyuki Sakaki (Univ. of Tokyo):
Quantum Wave
Prof. Hiroshi Masuhara (Osaka Univ.):
Microphotoconversion
Prof. Junya Mizutani (Hokkaido Univ.):
Plant Ecochomicals

89-94 Dr. Akira Tonomura (Adv Res Lab. HITACHI Ltd.):
Electron Wavefront
Dr. Masakazu Aono (Inst of Phys & Chem Research):
Atomcraft
Dr. Joh-E lkeda (National Institute of Agrobiographical Resources, M.A.F.F.):
GenoSPHERE

90-95 Dr. Shigeyuki Vimura (National Institute for Research in Inorganic Materials, S.T.A.):
Metamelt
Dr. Kuniaki Nagayams (Biometrology Lab. JEOL Ltd.):
Protein Array
Dr. Kunio Torii (Cent Res Lab. AJINOMOTO Co., Ltd.):
Nutrient-stasis
Prof. Seiji Shinkai (Kyushu Univ.):
Chemirecognics

91-96 Dr. Susumu Yoshimura (Matsushita Res Inst Tokyo):
Pi-Electron Materials
Prof. Ryoji Noyorl (Nagoya Univ.):
Molecular Catalysis
Prof. Nobuhiro Fusetani (Univ. of Tokyo):
Biofouling
Prof. Hirato Okayama (Osaka Univ.):
Cell Swithing

92-97 Prof. Kingo ltaya (Tohoku Univ.):
Electrochemiscopy
Prof. Koiji Kawachl (Univ. of Tokyo):
Millibioflight
Prof. Toshio Yanagida (Osaka Univ.):
Biomotron
Prof. Katsutoshi Yoshizato (Hiroshima Univ.):
Morphomatrix

Four new projects are scheduled to begin in October 1993, but their titles have not yet been published.)

(b) PRESTO

The Precursory Research for Embryonic Science and Technology program (PRESTO) was started in 1991 so that creative individuals could conduct basic research around their ideas. JRDC selects broad research areas that are expected to generate new science and technology. A general coordinating director is selected for each research area. These directors chair review committees that select the best

proposals received in response to broad solicitations. The selected researchers are hired by JRDC and conduct their research for three years in laboratories provided by JRDC. Each individual receives Japanese¥60M (or more) in research funds over the three years. The funds include salary, laboratory rental, and administration costs from JRDC. The research results are actively published and become intellectual property shared by JRDC and the individual researchers. The major distinction between PRESTO and ERATO projects is that the former are bottom up from the individual researcher who applies for funding within a general field, whereas the latter are essentially top down, driven by the project director who hires researchers to work under his direction. Both are of fixed duration.

PRESTO PROJECTS

Field		New Researchers Hired 91	92	93
Structure & Functional Property	Prof. Kazutake Kora (Director, Tsukuba Institute of Research and Education)	12	+4	+8
Light and Material	Prof. Kenichi Honda (Tokyo Institute of Polytechnics)	12	+4	+8
Cell and Information	Prof. Humio Osawa (Aichi Institute of Technology)	12	+4	+8

(NOTE: No new projects are planned for 1993.)

3. TECHNOLOGY TRANSFER (COOPERATIVE TECH DEVELOPMENT AND TECH TRANSFER FACILITATION)

JRDC promotes the transfer of research results to industry through High Technology Consortia, Cooperative Technology Development, and Technology Transfer Facilitation. The objective for all is to transfer research results effectively, to broaden the applications of research results, to actively promote development, and to raise the level of industry.

Cooperative Technology Development and Technology Transfer Facilitation have been activities of JRDC since its inception in 1961. Through Cooperative Technology Development, JRDC promotes the development of research that is difficult for industry to develop on its own. JRDC reduces the risks by providing no-interest funding that is repaid only if development is successful. If a company can bear the risks involved in developing a new technology by itself, JRDC acts as a technology transfer facilitator for the researcher and the company.

In 1986 JRDC began to establish High Technology Consortia to develop promising major research results that arise from ERATO, national laboratories, universities, and other sources. The idea is to bring companies together with researchers to explore new applications that hold potential for benefits to the participating companies.

In its oldest activity, facilitating the transfer of technology to industry, JRDC collects research results, and after studying the development risks for each result, JRDC directs higher risk technologies to Cooperative Technology Development and lower risk technologies to Technology Transfer Facilitation.

(a) COOPERATIVE TECHNOLOGY DEVELOPMENT

Technologies directed to Cooperative Technology Development are evaluated for novelty, economics, and public benefits. Those selected cannot be easily developed by industry alone. A Cooperative Technology Development contract is given to a company that is best suited for the development. As a rule, interested companies are publicly solicited. JRDC, the company, and the researcher

who first provided the technology plan together the scale, time, and funding for the development. JRDC then provides the necessary funds. The company carries out the development while receiving technical guidance from the researcher. JRDC provides the controls to ensure that development proceeds smoothly and efficiently.

At the end of the development period, JRDC decides whether or not it was successful by the criteria agreed upon at the beginning. If unsuccessful, the company does not need repay the funds received from JRDC. If the development is successful, the company repays the funds over a five-year period without interests. For a successful development, JRDC and the company form an agreement for commercializing the developed technology. JRDC receives royalties on the sales of the resulting products. As a rule, half of these royalties are passed on to the researcher. JRDC also works to distribute the technology to other companies besides the developing company.

Examples of Cooperative Technology Development projects are electron undulating ring/radiation, positron computed tomography, and development of gas sensors using amorphous metallic fine particles.

(b) TECHNOLOGY TRANSFER FACILITATION

Items directed to Technology Transfer Facilitation are publicized annually in publications introducing technologies available for license. JRDC also makes public presentations of new technologies that have broad application at about ten meetings held each year. JRDC also works to transfer technology through members of its Technology Transfer Facilitation Commission. When transferring a technology for development, JRDC becomes an intermediary and prepares the development contract. The company then develops the technology while receiving technical guidance from the researcher. If the development results in saleable products, JRDC collects royalties, and 80-90% of these are passed through to the researcher. In response to requests by foreign companies, JRDC technologies are made available for transfer worldwide.

An example of a Tech Transfer Facilitation project was the development of a high-vacuum degassing furnace made from Aluminum alloy.

(c) HIGH TECHNOLOGY CONSORTIA

As basic research improved in universities and through ERATO, a need became visible to provide for further evaluation and testing of the research results before proceeding with development. The High Technology Consortia were started in 1986 to carry these results forward while exploring their potential for practical use. From among the research results obtained from ERATO, national laboratories and universities, JRDC selects certain results that are expected to give rise to active advanced development in broad areas of technology. After formulating an evaluation plan, JRDC seeks the participation of companies from various fields. A consortium of diverse companies is formed, and evaluative testing is conducted to emanete new technologies. The researchers that produced the results upon which the consortium is based provide basic data needed for evaluation and also provide information and technical guidance to the participating companies. Each of the participating companies perform evaluative testing relating to their own particular fields and interests. JRDC may provide funds to companies that are viewed as particularly important for evaluating the technology. After completion of the consortium, the results that have potential commercialization are developed through Cooperative Technology Development and other mechanisms.

An example of a High Tech Consortia project is the one associated with development of amorphous metallic fine particles.

4. INTERNATIONAL RESEARCH EXCHANGE

The International Research Exchange program began in 1989 as one of several measures, in Japan, aimed at strengthening international cooperation in S&T. JRDC implements the STA Fellowship program that provides foreign researchers with opportunities to conduct research at Japan's national laboratories and at other organizations' laboratories. To help researchers identify opportunities, JRDC provides information on Japan's research activities to foreign organizations and researchers. Once the researchers come to Japan, JRDC helps to make their stay easier by providing housing and information on living in Japan.

(a) INTERNATIONAL JOINT RESEARCH PROGRAM

The International Joint Research program began in 1989. Its main objective was to promote basic research through international links between Japanese and foreign researchers based on equal sharing of talents and costs.

After JRDC and a foreign research agency reach agreement on an appropriate research area, JRDC and the counterpart each select talented researchers to lead complementary local research groups. An international joint project runs for five years with the total budget shared equally by JRDC and its counterpart — a budget of Japanese¥2-3B including personnel and laboratory costs. Each project is composed of about 20 researchers from industry, academia, and government. Laboratories are located where they can best serve the project, including in the counterpart organization, in universities, and in private industry. Research results are actively contributed to the literature, and intellectual property rights are shared by JRDC and the counterpart organization.

INTERNATIONAL JOINT RESEARCH PROGRAM PROJECTS

Term	Topic	Directors	Implementing-- Supporting Orgs (Research sites)
90-95	Atom Arrangement-Design and Control for New Materials (AADC)	JAPAN: Prof. Michio Yamazaki Nishitokyo University	JRDC
		UK: Prof. C.J. Humphreys (Cambridge) Prof. D. Hull (Liverpool) Prof. B.A. Joyce (University of London)	Cambridge Univ London (Sites: Cambridge, U London)
91-96	Microbial Evolution	JAPAN: Prof. Keiji Yano (Nagaoka U of Tech)	JRDC (Sites: Shinanogawa Technopolis, Riken Institute
		USA: Prof. J.M. Tiedje (Michigan State U)	(Site: Michigan State U Cent for Microbial Eco
92-97	Supermolecules	JAPAN: Prof. Toyoki Kunitake (Kyushu University) Prof. Jyunzo Sunamoto (Kyoto University)	JRDC (Sites: Kurume Research Park & site near Kyoto U)
		FRANCE: Prof. J.A. Osborn (Louis Pasteur U)	Site: Louis Pasteur U
93-98	Sub HEMT (10^{-15}) Biorecognition	JAPAN	(Sites: Hamamtsu Photonics, Nat Res Lab for Radio Isotope & Med Res, Osaka Bio Inst)
		SWEDEN	(Site: Uppsala Univ)

(b) STA FELLOWSHIPS

The STA Fellowship program was established to provide foreign researchers with opportunities to conduct research in those Japanese national laboratories and public corporations that are not part of the university system. Fellowships are offered to younger (age 35 or younger) researchers who possess a Ph.D. or equivalent qualifications. Research topics are selected by the fellowship recipients within the limitations of their host institutions. The fellowships provide round-trip transportation to and from Japan, living expenses, family allowances, housing allowances, domestic travel expenses and limited research funds.

NUMBER OF STA FELLOWSHIPS

FY88	100
FY89	130
FY90	160
FY91	180
FY92	185
FY93	215

(NOTE: In 1992, approximately 25 of the fellowships were given to scientists from the United States.)

A related organization is JISTEC (Japan International Science and Technology Exchange Center). It was founded in 1990. JISTEC is a private nonprofit foundation with two major functions. First, under contract from JRDC, JISTEC manages the STA Fellowship program described above, and operates all necessary logistical services associated with that. Second, JISTEC acts as a "marriage broker" between foreign scientists and Japanese private research institutions to help the latter fill staff positions in their research labs. (For this second function, approximately 190 member companies pay JISTEC an annual fee.)

(c) LIVING SUPPORT FOR FOREIGN RESEARCHERS

JRDC established Takezono House, an apartment building for foreign researchers who conduct research at the national laboratories and public corporations in the Tsukuba area and for their families. Information on life in Japan is provided to foreign researchers who are planning to come to Japan so that they can better plan for their stays. A counseling service is provided to foreign researchers and families who run into difficulties while living in Japan. Japanese language training is also provided to foreign researchers and their families. And a Japanese language training videotape is distributed to foreign research organizations for use by their personnel. (Living support is primarily contracted to JISTEC as I have mentioned above.)

(d) JRDC INTERNATIONAL NETWORK

JRDC is setting up the JRDC International Network, accessible through BITNET. In order to promote human research exchange, JRDC provides information about Japan's national laboratories, their researchers, and their research areas. JRDC also holds international symposia. One is planned for June 1993 in Louvain, Belgium.

5. JRDC PUBLICATIONS

1. Common to all JRDC

   a. JRDC News: Quarterly in Japanese
   b. News Release: Occasionally in Japanese

2. Basic Research

   a. ERATO Symposia
      Semi annually, primarily in Japanese
   b. ERATO project's final symposia
      At the end of each project, primarily in Japanese

3. Technology Transfer

   a. New Technology Journal: Yearly in Japanese
   b. Opportunities for License: Yearly in English
   c. New Technology Presentation: 10 times/year in Japanese
   d. ERATO Research Results (ERATECH): In English and Japanese

4. International Research Exchange

   a. JRDC International symposia: Yearly in English
   b. Directory of Nat Labs and Public Corporations: Yearly in English

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☐ **New** ☐ **Change** ☐ **Delete**

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